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WEAPONS AND TACTICS INSTRUCTOR COURSE 2-16 SLEEP AND PERFORMANCE STUDY

by

Rachel A. Gonzales

March 2017

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The Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) command requested a sleep and performance study of the instructors and students of Weapons and Tactics Instructor (WTI) course 2-16. Specifically, MAWTS-1 leadership wanted to know whether crew rest periods were being used for sleep and whether fatigue posed a risk to personnel during the course. This thesis expanded upon prior studies in military educational environments. The WTI 2-16 study collected sleep and performance data via wrist-worn actigraphy and psychomotor vigilance tests (PVT). Sleep duration and efficiency remained high throughout the course, but participation waned before the study ended. Both instructors and students appeared to receive adequate sleep of good quality (overall mean 7.4 hrs/night). There was little variability in the sleep patterns (i.e., WTI participants were abiding by the crew rest regulations). Compliance posed a significant challenge and limited the ability to correlate sleep to performance. We also measured self-reported fatigue and mood using standardized questionnaires. Results from subjective assessments showed a significant increase in self-reported fatigue as the course progressed. This thesis outlines a detailed methodology and lessons learned for follow-on studies of this type and recommends improvements to future studies.

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WEAPONS AND TACTICS INSTRUCTOR COURSE 2-16 SLEEP AND PERFORMANCE STUDY

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ABSTRACT

The Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) command requested a sleep and performance study of the instructors and students of Weapons and Tactics Instructor (WTI) course 2-16. Specifically, MAWTS-1 leadership wanted to know whether crew rest periods were being used for sleep and whether fatigue posed a risk to personnel during the course. This thesis expanded upon prior studies in military educational environments. The WTI 2-16 study collected sleep and performance data via wrist-worn actigraphy and psychomotor vigilance tests (PVT). Sleep duration and efficiency remained high throughout the course, but participation waned before the study ended. Both instructors and students appeared to receive adequate sleep of good quality (overall mean 7.4 hrs/night). There was little variability in the sleep patterns (i.e., WTI participants were abiding by the crew rest regulations). Compliance posed a significant challenge and limited the ability to correlate sleep to performance. We also measured self-reported fatigue and mood using standardized questionnaires. Results from subjective assessments showed a significant increase in self-reported fatigue as the course progressed. This thesis outlines a detailed methodology and lessons learned for follow-on studies of this type and recommends improvements to future studies.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADT&E	Aviation Development, Tactics, & Evaluation
AGS	Aviation Ground Support
AMI	Ambulatory Monitoring Incorporated
AOD	Aircraft Operations Division
BAC	Blood Alcohol Concentration
BMI	Body Mass Indexes
C-3	Operations and Training
CO	Commanding Officer
DOD	Department Of Defense
EEG	Electroencephalograms
EOG	Electro-Oculograms
ESS	Epworth Sleepiness Scale
FAST	Fatigue Avoidance Scheduling Tool
FINEX	Final Combined Arms Exercise
FS	False Start
GCD	Ground Combat Division
GPA	Grade Point Averages
GS	Gold Standard
HQ	Headquarters
IRB	Institutional Review Board
ISI	Insomnia Severity Index
ISI	Inter-Stimulus Interval
Lim	Limited
MAGTF	Marine Air Ground Task Force
MANOVA	Multivariate Analysis Of Variance
MAWTS-1	Marine Aviation Weapons and Tactics Squadron One
MCS	Millennium Cohort Study
MEQ	Morningness-Eveningness Questionnaire
MOS	Military Occupational Specialty
MRI	Magnetic Resonance Images
NATOPS	Naval Air Training and Operating Procedures Standardization
NHTSA	National Highway Traffic Safety Administrations
NPS	Naval Postgraduate School
P	Partial
POMS	Profile of Mood State
POMS A	Profile of Mood State Anger-Hostility
POMS C	Profile of Mood State Confusion-Bewilderment

POMS D	Profile of Mood State Depression-Dejection
POMS F	Profile of Mood State Fatigue-Inertia
POMS T	Profile of Mood State Tension-Anxiety
POMS V	Profile of Mood State Vigor-Activity
PSD	Partial Sleep Deprivation
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
PVT	Psychomotor Vigilance Test
REM	Rapid Eye Movement
RT	Response Time
SAFTE	Sleep, Activity, Fatigue, and Task Effectiveness
SAIC	Science Applications International Corporation
SD	Sleep Deprivation
SOL	Prolonged Sleep Onset Latency
TACAIR	Tactical Aviation
TECOM	United States Marine Corps Training and Education Command
TIB	Time in Bed
TMD	Total Mood Disturbance
TRM	Tactical Risk Management
TSD	Total Sleep Deprivation
WASO	Frequent Waking After Sleep Onset
WRAIR	Walter Reed Army Institute of Research
WTI	Weapons and Tactics Instructor Course
ZCM	Zero Crossing Mode

EXECUTIVE SUMMARY

The Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) command requested a sleep and performance study of the instructors and students of Weapons and Tactics Instructor (WTI) course 2-16. Specifically, MAWTS-1 leadership wanted to know if crew rest periods were being used for sleep and if fatigue posed a risk to personnel during the course. This thesis expanded upon prior studies in military educational environments. Participation, compliance, and data processing efficiency were three major challenges that resulted in difficulty correlating sleep to performance. However, valuable insight was gained through the variety of data collected and this thesis outlines a detailed methodology, lessons learned, and recommendations for follow-on analysis and improvements to future studies.

The focus of this thesis was to determine, outside of a structured laboratory environment, if the performance of an individual participating in WTI 2-16 course was impacted by either the quantity or quality of sleep received. This question was addressed using various objective and subjective measures of performance and fatigue. Sleep quantity and quality were evaluated using actigraphy data from 11 staff members and six students. Subjective data included three sets of questionnaires collected throughout the course. Specifically, differences in the time across the self-reported POMS TMD, POMS F, and ESS scores from 52 participants were statistically significant.

In general, results from the objective sleep data showed that throughout the course, there was good sleep quantity and quality. Based on the individual mean sleep durations of 17 participants with actigraphic recordings for the entire course, mean participant sleep duration for WTI 2-16 was 7.40 hours (7 hours and 24 minutes) with a standard deviation of 0.48 hour (29 minutes). Mean participant sleep efficiency for the course was 95.06% with a standard deviation of 2.52%. Furthermore, nights in the course that appeared to have a lower average amount of sleep were followed by nights with greater than average sleep. This finding confirmed that students and instructors were using crew rest periods effectively.

An additional research question considered if there was any portion of the curriculum where either students or the staff were sleep deprived. Based on the objective actigraphic data collected, insufficient sleep did not appear to be an issue. However, results from the questionnaires, specifically an increase in the POMS Fatigue subscore and an increase the number of participants reporting ESS scores >10, indicate that self-reported fatigue increased over the course. In particular, the POMS F scores for all participants worsened over the course of the study. The changes for the student group were reflected in p-values = 0.01 between the second and third administration and the first and third administration. For the staff, the changes in POMS F scores were more severe and were reflected in p-values <.001 between the second and third administration and the first and third administration.

Objective performance data, collected in the form of psychomotor vigilance tests (PVT) scores, showed consistent performance throughout the course with respect to speed and accuracy for PVTs. However, the staff appeared to have consistently faster response times and fewer errors than the students. With the objective data showing overall good sleep habits for study participants and consistent PVT performance, there was no evidence to suggest that poor sleep patterns have a negative effect on performance. Additionally, the collection of this data outside of a structured laboratory environment helped identify several of the challenges in cleaning and processing the information and led to the development of a repeatable process that could be refined or automated as part of future work.

This thesis also compared these results to the WTI 2-05 course results. For WTI 2-05 (n = 20), nightly sleep averaged 7.05 hours (7 hours and 3 minutes) with a standard deviation of 0.48 (29 minutes) but did not report sleep efficiency (Maynard, 2008). As previously mentioned, the 17 WTI 2-16 GS participants' mean sleep duration was 7.40 (7 hours and 24 minutes) with a standard deviation of 0.48 (29 minutes) with typically high sleep efficiency. This comparison suggests that average sleep duration has remained relatively consistent for the WTI staff and students over the past 10 years.

References

Maynard, P. L. (2008). *Marine aviation weapons and tactics squadron one (MAWTS-1) sleep, fatigue, and aviator performance study* (Master's thesis). Retrieved from Calhoun http://calhoun.nps.edu/handle/10945/3747.

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I. INTRODUCTION

A. UNITED STATES MARINE CORPS

The United States Marine Corps (USMC) is an organization that prides itself on the ability to do more with less (Riley, 1987; Priest, 1990, Brush 1991; Munson 2010). With approximately 182,000 active-duty personnel, the Marine Corps has the fewest number of personnel among the uniformed services and typically receives the smallest budget (Department of Defense [DOD], 2016). One characteristic of the Marine Corps is the requirement of its members to maintain some of the most challenging body composition and physical fitness standards (Le, 2016). Furthermore, like all uniformed services within the DOD, the Marine Corps consistently expect the highest levels of leadership and professionalism throughout all ranks. However, high expectations of mission accomplishment, coupled with high operational tempos and manpower shortages, can lead to sacrifices in the rest and recovery needed to achieve safe and effective performance in both training and combat. Although not uniformly directed throughout all areas of the Marine Air Ground Task Force (MAGTF), the aviation community has well-known publications that develop this knowledge and dictate strict, detailed procedural requirements regarding rest for both aviators and aircrew.

1. Current Orders and Directives

Two primary sources, the Department of the Navy, Naval Air Training and Operating Procedures Standardization (NATOPS) General Flight and Operating Instructions and the *Performance Maintenance during Continuous Flight Operations* Navy medical manual P-6410 (NAVMED P-6410) outline the importance of sleep safety to Marine Corps Aviation. Section 8.3.2.1.1 ("Crew Rest for Flight Crew and Flight Support Personnel") of OPNAVINST 3710.7U establishes the current governing policies. OPNAVINST 3710.7U states that crew rest begins when official duties end and is the "non-duty time before a flight duty period" including meals, commute, and rest (2004). The order mandates 8 hours of uninterrupted sleep time every 24 hours, dictates that flight crews should not be on flight duty in excess of 18 continuous hours and that if they

do, they should receive a minimum of 15 hours of continuous off-duty time before any subsequent flights (2004). If a mission requires a 24-hour work/rest schedule (for example in a combat situation), the crew rest can be reduced to less than 12 hours but must still account for an 8-hour sleep window. OPNAVINST 3710.7U further details specific consequences to a person's performance following a continuous awake period of greater than 16 hours. These consequences include an overall functioning of 75% effectiveness or less as well as "lapses in attention, increased reaction time, slowed information processing, decreased vigilance, and increased error frequency" (2004, p. 8-15). Furthermore, OPNAVINST 3710.7U acknowledges the increased risk of an accident in any activity following 18 hours of wakefulness and emphasizes this risk at night. A discussion regarding circadian rhythm and various accommodations that should be put into place for shift work and the jet lag resulting from crossing multiple time zones is also provided. Several paragraphs address the importance of adequate rest, nutrition, exercise, and hydration along with the responsibilities of leadership to enforce all of these (2004).

OPNAVINST 3710.7U does not specifically discuss measures to counter fatigue in aviation but references the NAVMED P-6410 *Performance Maintenance During Continuous Flight Operations* manual (2004). This thorough publication provides education and guidance on acknowledging and handling fatigue (Brown & Baker, 2000). Most notably, NAVMED P-6410 states that, "fatigue is not caused by lack of motivation or attitude" (Brown & Baker, 2000, p. 2). Furthermore, this reference draws attention to the fact that leadership will most likely receive less sleep especially prior to important missions, and that an individual cannot accumulate sleep (p. 4). NAVMED P-6410 also encourages the use of "combat naps of 10 minutes or more" when possible during sustained operations and clearly prioritizes sleeping over resting (Brown & Baker, 2000, p. 4).

For countering fatigue, NAVMED P-6410 briefly addresses both non-pharmacologic strategies such as "deferral of routine non-flying duties, flexible scheduling, and use of frequent naps" (Brown & Baker, 2000, p. 8) as well as detailed information on several pharmacological interventions to aid aviators in either falling asleep or staying awake. Approved stimulants for use in staying awake are Dexedrine, an amphetamine that impacts the central nervous system, and caffeine. Dexedrine is

recommended in no more than a 5-mg dosage, and users should be cautious so as not to overdose (Brown & Baker, 2000, pp. 8–9). Caffeine is convenient and has low abuse potential so it offers a high utility; although it is not as good as amphetamines in improving cognitive performance (Brown & Baker, 2000, pp. 8–9). However, NAVMED P-6410 cautions in several sections that the use of caffeine should be limited to be most effective ((Brown & Baker, 2000, pp. 8–9). Two benzodiazepines approved to help initiate sleep are Temazepam (Restoril) and Ambien (Zolpidem). Temazepam (Restoril) is recommended in a 15-mg dosage; higher dosage increase hangover effects and do not necessarily improve sleep). Ambien (Zolpidem) is also recommended but without giving a specific dosage. Both medications require a minimum of seven hours after taking the drug prior to flying ((Brown & Baker, 2000, pp. 8–9). NAVMED P-6410 cautions against repetitive dosing and medication interactions and acknowledges the importance of monitoring side effects as well as the importance of self-regulation. One of the strongest features of this particular publication is its outline of strategies at each level of leadership to help counter fatigue.

While these two resources (OPNAVINST 3710.7U and NAVMED P-6410) clearly outline regulations and provide information regarding sleep and aviation, they also present two concerns. The first is that similar rules, regulations, and guidance do not exist for other areas of the Marine Corps (i.e., those occupations outside of the aviation community). The second challenge, and the focus of this thesis, is finding a way to enable leadership to practically monitor sleep and performance in an effort to increase combat effectiveness, reduce unnecessary risk, and avoid fatigue related mishaps without detracting from a Marine's performance.

2. Marine Aviation Weapons and Tactics Squadron One (MAWTS-1)

Since the 1950s, the Marine Corps has sought to "disseminate weapons and tactics training and information" to aviation units via subject matter experts (Jans, n.d.). In 1978, Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) assumed responsibility for this challenging mission. Located in Yuma, Arizona, MAWTS-1 continues to operate today under the guidance of the United States Marine Corps

Training and Education Command (TECOM). With a total staff of less than 200, MAWTS-1 oversees the aviation training and readiness manuals for the Marine Corps, as well as several large training evolutions each year in support of all areas of the Marine Air Ground Task Force (MAGTF).

3. Weapons and Tactics Instructor Course (WTI)

MAWTS-1 is responsible for the Weapons and Tactics Instructor Course (WTI) that is run semi-annually and produces nearly 300 graduates each year. While the seven-week WTI course primarily focuses on developing company and field grade aviators into highly proficient squadron training officers. Selected aviation ground support providers (communicators, logisticians, engineers, and maintainers) as well as ground combat fighters (infantrymen, tankers, and artillerymen) also attend. Students and staff are broken down into the following divisions: Aviation Development, Tactics, & Evaluation (ADT&E), Aviation Ground Support (AGS), Aircraft Operations Division (AOD), Operations and Training (C-3), Ground Combat Division (GCD), Headquarters (HQ), and Tactical Aviation (TACAIR).

The WTI course is divided into an academic phase and a flight phase. Within the three-week academic phase, students review, improve, and demonstrate mastery of basic aviation knowledge. Additionally, during this time, Tactical Risk Management (TRM) training educates students on how to, in the words of former MAWTS-1 Commanding Officer (CO) Colonel Bradford J. Gering, “assess operational risk and mitigate it as a part of a training plan” (as cited in Jans, n.d.). The academic phase transitions into a commons phase which combines operators of similar communities and concludes with students focusing on the specifics of their individual platform or military occupational specialty (MOS). The flight phase of the curriculum gives students the opportunity to demonstrate individual skills and integrates them among other Marine Corps communities. During this time, students assume various leadership roles for mission planning and execute a variety of tasks across the range of military operations. The entire course culminates with a final combined arms exercise, referred to as FINEX, which integrates a Marine Expeditionary Brigade’s worth of personnel, equipment, and capabilities. At its conclusion, the specific

course conducted from 6 March 2016 through 24 April 2016 was WTI 2-16. This course graduated 167 officers and 74 enlisted personnel.

4. Study Request

Although MAWTS-1 has a mission focus dedicated toward aviation units, the elite staff and students trained through this institution can significantly affect all areas of the Marine Corps and set high, informed standards as leaders. Prior to the spring course convening, the Commanding Officer of WTI, Colonel J. A. Adams, requested a study on "sleep patterns, cumulative fatigue, and performance" be conducted during the WTI 2-16 course (personal communication, January 8, 2016). The intent of the study was to enhance the TRM program, to inform the command, staff and students of issues pertaining to fatigue and performance, and shape curriculum development in the future (personal communication, January 8, 2016). Results from a similar study conducted during WTI 1–06, following implementation of a fatigue countermeasures program, can be seen in a Naval Postgraduate School (NPS) thesis by Maynard (2008). While that study determined that the WTI 1–06 students were not chronically sleep deprived and did not find a significant or practical significance between sleep and performance, Maynard (2008) speculated that a larger sample size and longer study duration might yield different results. The details of Maynard's thesis will be discussed further in the literature review but are served as one of the motivating factors for this study. In reexamining the idea of studying sleep, fatigue, and performance among the MAWTS-1 staff and WTI students, military leadership as well as researchers desired to take advantage of improved technologies, a larger sample size, and longer study time to either refine previous results or further contribute to improvements in sleep and safety culture within the Marine Corps.

While it is not always possible to ensure military personnel receive adequate sleep in a combat environment, leadership can control rest period within academic training and field rehearsal environments. The purpose of this study was to examine whether the sleep quantity and quality of WTI 2-16 participants affected an individual's performance. Instructors and students involved with WTI are prime candidates for this research

because they are best situated in the Marine Corps to influence the operating forces regarding the importance of such research. Additionally, the ever-present need to mitigate risk and reduce safety or training related mishaps continually motivates service leadership to explore ways in which to optimize an individual's ability to respond in various environments. Increasing concerns throughout the DOD on the mental health and wellbeing of service members both on active duty and after separation have led to a heightened focus on the importance of ensuring proper rest (Seelig et al., 2016). Specifically, MAWTS-1 leadership wanted to find ways to improve the course as well as student and staff performance. This thesis evaluates the results of the sleep and performance data collected over seven weeks of the WTI 2-16 course.

B. OBJECTIVE

1. Research Questions

The primary research question addressed by this thesis is whether

- the quantity and quality of sleep of an individual participating in WTI 2-16 course affect performance.

Additional research questions included the following:

- Are the WTI participants (students/instructors) chronically fatigued at any point in the WTI course?
- Are WTI participants (students/instructors) using crew rest periods to reduce sleep deficits?
- Do WTI student sleep patterns affect performance (i.e., academic/flight/attrition)?
- Is the current WTI event schedule balanced with regard to crew rest opportunities?
- Could factors affecting sleep quality be improved (e.g., room assignments, environment control, light exposure)?
- How do the results of the 2006 study compare to the results of the 2016 study?

"Performance" is a broad and generic term that can take on several different meanings and is often difficult to categorize and capture. Specifically for this research,

the Psychomotor Vigilance Test (PVT), exam scores, and course attrition comprised the measures of an individual's performance. Although this thesis focuses on a specific group of Marine Corps students and instructors operating in a fairly structured course, the long-term desire is to continue to improve the quality of training, combat performance and overall well-being of all service members and provide commanders with realistic and practical sleep and performance feedback.

C. THESIS ORGANIZATION

This thesis is organized into five chapters. Chapter I contains an introduction and general background information. Chapter II presents a literature review that focuses on the current research pertaining to sleep and performance as well as sleep research and performance in the military. Chapter III delivers a detailed methodology that outlines how the study was conducted. Chapter IV summarizes the analysis and results and Chapter V provides additional discussion, lessons learned, and recommendations for future work.

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II. LITERATURE REVIEW

A. OVERVIEW

The purpose of this literature review is to inform the reader of the current state of research pertaining to sleep and performance in a military training and education environment. First, the reader must understand the basics of sleep, circadian rhythm, and sleep deprivation. With this foundation, the chapter reviews the profound impact that insufficient sleep quantity and quality have on both simple and complex cognitive tasks. Additionally, this chapter explores current research pertaining to learning, memory, and insufficient sleep. Military-specific examples gathered from both laboratory and field environments supplement these understandings. In conclusion, the chapter evaluates the collection of work conducted at NPS that focuses on sleep and performance research in military training and education environments. The purpose of the current research is to analyze both objective and subjective sleep and performance data gathered from the WTI 2-16 students and staff in order to assess the impacts of sleep quantity and quality on performance in a military training environment. A review of the literature supports not only an understanding that insufficient sleep directly impacts cognitive performance but also demonstrates that in the areas of learning, memory, and skill acquisition further research is needed to better understand the full impact of sleep deprivation.

B. SLEEP, CIRCADIAN RHYTHM, AND SLEEP DEPRIVATION

Prior to discussing the impacts of insufficient sleep, the reader requires a basic understanding of sleep. The online Merriam-Webster dictionary provides the following medical definition of sleep: “the natural periodic suspension of consciousness during which the powers of the body are restored” (n.d.). Adult humans require between seven and eight hours of sleep each night, but what happens in those sleeping hours and the consequences of not receiving enough sleep are not well understood (Anch, Browman, Mitler, & Walsh, 1988). In 1937, Loomis began studying the various stages of sleep (Loomis, Harvey, & Hobart, 1937). Since then, researchers have arrived at fairly universal understandings of human biological circadian rhythms as well as of the various

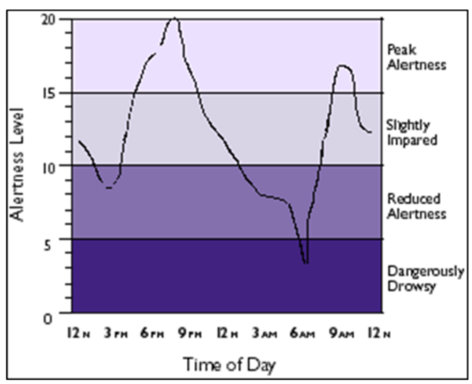
sleep stages. The method considered the gold standard in the study of sleep quantity and quality is polysomnography (PSG) (Blackwell et al, (2008)). PSG is the term used for a sleep study that monitors various brain waves through electroencephalograms (EEG) and/ or eye movements through electro-oculograms (EOG) (Miller, Matsangas, & Shattuck, 2007). This field of research has continued to reveal more details about the sleep cycles and stages of sleep. Although the most reliable, this method of studying an individual's sleep must be conducted in a laboratory environment and is not practical for field research such as with a military population.

Readers should be aware that circadian rhythms influence an individual's quality of sleep. Circadian rhythm refers to predictable changes in physiological processes (such as alertness) occurring throughout the 24-hour day. Environmental cues like sunlight and the timing of meals drive circadian rhythm. These cues are known as "zeitgebers" (Miller et al., 2007). Wright, Lowery, and Lebourgeois thoroughly discuss the critical role this internal time keeping system plays in regulating our emotions, hormones, and our ability to learn through the interactions of various chemicals in the brain (2012). Figure 1 shows the ebb and flow of an individual's alertness over a 24-hour period in response to typical circadian rhythms. Advances in electricity and lighting have introduced artificial environments that often encourage people (either by choice or necessity) to adopt work and rest patterns that result in circadian misalignments that can potentially lead to metabolic disorders and other diseases (Potter et al., 2016). A lifestyle that is synchronized with a person's circadian rhythm is just one example of good sleep hygiene and helps to improve overall sleep quality.

Insufficient sleep can be categorized as reductions in both sleep quantity and quality contribute to sleep deprivation (SD). SD can be categorized in two ways: partial sleep deprivation (PSD) and total sleep deprivation (TSD). PSD is an acute condition that occurs when small amounts of sleep are lost over the span of days or weeks (Miller, Matsangas, & Kenney, 2011). TSD occurs when an individual has no opportunity to sleep (Miller et al., 2011). An awareness of PSD and TSD is important in a military population because both types of SD can occur as a result of routine mission requirements, training evolutions, and combat. Lack of sleep has been associated with a variety of health issues.

These include the following: gastrointestinal issues, breast cancer, metabolic disorders, reduced immunity, and higher body mass indexes (BMI) (Potter et al., 2016). Furthermore, "sleep deprivation impairs alertness, cognitive performance, and mood" (Belenky et al., 1994, p. 128). Lim and Dinges (2008) captured the consequences of sleep deprivation by stating that, "the link between sleep and the capacity to attend to external stimuli is both intimate and inextricable. To the nonexpert, this fact may seem so intuitive as to be almost trivial" (p. 305). Lim and Dinges (2008) expand on a body of literature concluding that a lack of sleep results in a loss of vigilance which can result in "devastating real-world consequences" (p. 206).

Figure 1. Daily Circadian Rhythm. Source: National Highway Traffic Safety Administrations (NHTSA) (2007).



C. MOTIVATION FOR MILITARY SLEEP RESEARCH

Decades of sleep studies conducted by researchers on the military demonstrate a long history of concern over this topic by both academics and leaders. However, a great deal of work needs to be done. Data provided between 2001–2008 by the ongoing longitudinal analysis Millennium Cohort Study (MCS) concluded that within a United States Military population self-reported insomnia was significantly correlated with "lower self-rated health, more lost work days, lower odds of deployment, higher odds of early discharge from military service, and more health care utilization" (Seelig et al., 2016). Although an ongoing longitudinal study, this information has been collected on a large and diverse group of military members (n = 55,021); information regarding these

early findings can be used to influence current military leaders and law makers (Seelig et al., 2016). Of specific interest to the military are the impacts that reduced sleep has on immediate performance (both psychomotor performance as well as decision making) and the long-term implications of decreased physical performance and low resiliency. Immediate performance implications of insufficient sleep include increased injury, accidents, and mishaps leading to lost work hours, damaged equipment, and even death. Longer-term implications of insufficient sleep encompass decreased physical performance and low resiliency that can result in lost work hours, negative impacts to an individual's retention and promotion, and an increase in the requirement for prolonged medical care. Although the MCS study does not use objective methods such as actigraphy to quantify sleep, early findings of the study suggest that military leadership should increase efforts across the board to promote and improve sleep hygiene for gains in both short- term performance and long-term resiliency (Seelig et al., 2016).

D. IMPACT OF INSUFFICIENT SLEEP PERFORMANCE

Much literature supports the idea that sleep deprivation affects several areas of performance. In both laboratory research and military field environments, studies demonstrate an impact of sleep deprivation on cognitive performance. Of particular importance to this study is the impact that sleep quantity and quality have in a training environment where a focus is placed on learning, memory, and skill acquisition. A better understanding of the impacts that insufficient sleep has in a training environment can lead to further reduction in real-world mishaps both in military combat and everyday life.

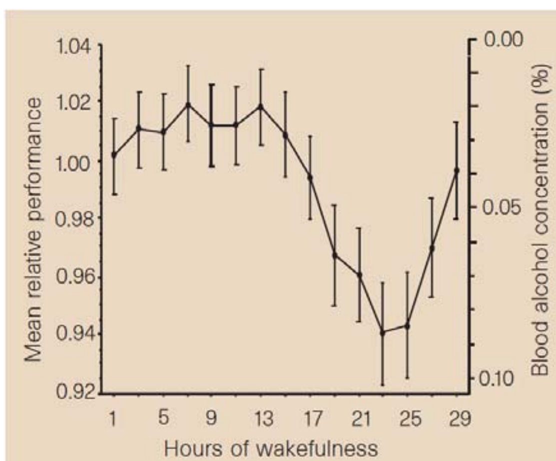
1. Cognitive Performance

Sleep deprivation has been shown to have a direct effect on cognitive performance. Cognitive performance encapsulates an individual's attention, vigilance, learning, memory, and decision-making processes. Studies in this field focus on the effect that either partial or total sleep deprivation has on a person's reasoning skills and reaction time (speed and accuracy). Scientists attribute the impact to the effect that sleep has on a person's prefrontal cortex and executive functions (Harrison & Horne, 2000)). Simply put, "sleep deprivation compromises our ability to pay attention" (Lim & Dinges, 2008,

p. 205). Furthermore, a literature review of several studies by Miller, Matsangas, and Shattuck (2007) conclude that there is a "profound effect of both acute and chronic sleep loss on cognitive performance" (p. 246).

Several laboratory studies have examined the impacts of insufficient sleep on cognitive performance. One landmark sleep and performance study has been the work done by Dawson and Reid (1997) which compares 20 sleep deprived participants and 20 participants consuming alcohol. Computerized PVT measured the cognitive performance of individuals during a 24-hour period. The results, displayed in Figure 2, demonstrate the decreases in mean relative performance with hours of wakefulness and illustrate the equivalent blood alcohol concentration (BAC) level. In all 50 of the United States, a BAC of .08% is considered legally intoxicated. This level is .04% for commercial drivers. Figure 2 shows that prolonged wakefulness of over 20 hours approaches this intoxication limit.

Figure 2. Mean Relative Performance vs. Hours of Wakefulness as a function of Blood Alcohol Concentration (BAC). Source: Dawson and Reid (1997).

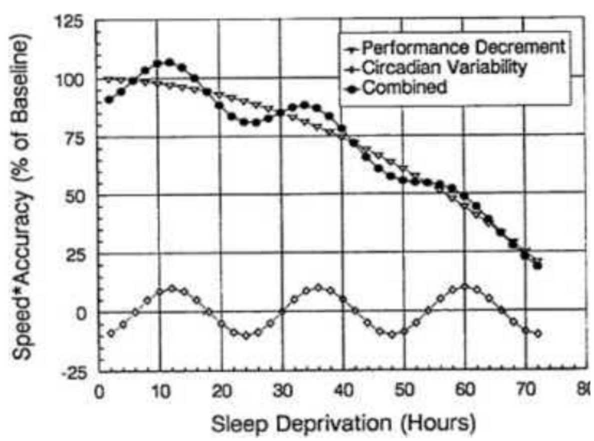


Performance in the sustained wakefulness condition expressed as mean relative performance and the percentage blood alcohol concentration equivalent. Error bars +/- standard error of the mean.

In a different area of cognitive research, Dinges et al. (1997) focus on the impact that insufficient sleep has on mood and performance. In a laboratory setting, 16 participants received 2 baseline days of sufficient sleep, followed by seven days of sleep

restriction (5 hours per night) and one day of recovery. This experiment concludes, "a clearly measurable effect on neurobehavioral markers of alertness, especially measures of sleepiness, fatigue, mood disturbances, stress, and PVT performance lapsing [errors of omission]" (Dinges et al.,1997). In particular, this study highlights that participants' self-reports of fatigue leveled off after the first two days of sleep restriction while reaction accuracy continued to degrade (Dinges et al., 1997). Using computer-based performance tests, Thorne, Genser, Sing, and Hegg (1983) conclude that there is a preservation of task accuracy at the expense of speed when volunteers operated with 72 hours of sleep deprivation. Figure 3 illustrates the findings of Thorne et al. with a decline of 25% in overall performance for every consecutive 24hr period (1983). Unfortunately, all of these prior studies involve participants observed only in a laboratory setting for a limited amount of time. The current study seeks to overcome these limitations by measuring performance in a training environment over an extended period of time (six weeks).

Figure 3. Sleep Deprivation and Circadian Variability.
Source: Thorne et al. (1983).



Speed Accuracy as a Result of Effect of 72h of total sleep deprivation on cognitive performance of normal volunteer subjects. The combined curve is decomposed into circadian variability and a negatively accelerating decrement in performance.

Though it is widely accepted that sleep deprivation impairs cognitive performance it has also been shown that this effect can be overcome in the case of simple tasks through the use of incentives and motivation. The same does not hold true of more complex reasoning. Of particular interest to military leadership is the impact that

insufficient sleep has on decision making. Belenky et al. establish that although "simple psychomotor performance and physical strength and endurance are unaffected by sleep deprivation"…"the most complex mental functions, including the ability to understand, adapt, and plan under rapidly changing circumstances" degraded as a result of sleep deprivation (1994). In a thorough literature review, Harrison and Horne reinforce these findings and demonstrate the consensus among sleep and fatigue researchers that the sensitivity of simple tasks (such as PVTs, IQ tests, and logical rule based actions) to sleep deprivation can be overcome with sufficient motivation or incentive (2000). However, Harrison and Horne specify that unlike simple tasks, decision making in a complex and uncertain environment (like a military combat situation) are in fact more sensitive to sleep deprivation due to their reliance on the "integrity of the prefrontal region of the cerebral cortex" which is shown in imaging scans "to be particularly affected by a night of sleep deprivation" (p. 237). Understanding these impacts is important to the current study because as both military leaders and operators of complex equipment systems, the students and staff of WTI rely heavily on the ability to make accurate and timely decisions.

Research has attempted to pinpoint specific areas of cognitive performance affected by sleep deprivation in military training environments. A field study conducted by Banderet, Stokes, Francesconi, Kowal, and Naitoh (1981) involved four artillery teams tested over a maximum time of 80 hours of continuous operations. After 36 hours of continuous operations, the teams encountered such problems as lost accountability for mission critical requirements, failure to update timely map information, and a tendency to procrastinate on previously urgent tasks (1981). May and Kline (1987) furthered this area of research by offering 135 soldiers a series of three cognitive exams over 10 weeks of intense training. Initial baseline examination was followed by two exams that were administered after participants were placed in a state of cognitive fatigue from either 48 hours with no sleep or a single day of extensive or difficult training) (May & Kline, 1987). The results show that when the tests were adversely affected by sleep loss it was a result of either visual encoding or a result of lapses of attention critically affecting performance (May & Kline, 1987). Both of these prior studies specifically targeted

performance in imposed fatigued states rather than observing whether individuals voluntarily placed themselves into a state of sleep deprivation (1987). Although the WTI curriculum allows for crew rest periods, these are opportunities to rest and recovery and are not strictly regulated or monitored and could potentially be used for purposes other than sleep.

Poor sleep quality can be as detrimental to performance as insufficient sleep. In an early study, Bonnet et al. (1987) used two test groups to establish that fragmented or frequently interrupted sleep destroyed its recuperative effects and that this held true even when the subject was unaware that sleep had been interrupted. Following this logic, Belenky et al. connected this critical finding to the fragmented sleep often achieved by military leaders in continuous combat operations (1994). As emphasized by Shay, military officers have a responsibility for self-care that includes prioritizing sleep and "stoic self-denial" only jeopardizes the success and safety of a unit (1998). Drawing on these prior studies, Olsen, Pallesen, Torshiem, & Espevik (2016) focus on the performance of 16 Norwegian Naval Officers in a controlled but operationally realistic scenario to evaluate the impact sleep deprivation has on three leadership styles (transformational, transactional, and passive avoidant). The findings of this study demonstrated that sleep was a contributing factor in leadership performance and that sleep-deprived leaders tended to resort to a more passive-avoidant leadership style and potentially shirk responsibilities (Olsen et al., 2016). One goal of the current study is to determine whether there is a particular time in the WTI curriculum causes individuals to receive a lesser quantity or lower quality of sleep and whether this has a subsequent impact on their performance.

2. Learning, Academics, and Skill Acquisition

The fields of academic learning, memory, and skill acquisition contain an enormous body of literature, but, several studies and literature reviews pertain to the impact that sleep (or lack thereof) has on each of these areas. What this collection of literature demonstrates is that each of these areas feature complex processes, whether physiological or cognitive, with multiple levels, and stages. Furthermore, the literature

suggests strong evidence that sleep plays a large role in developing memory, supporting learning, and improving skill acquisition. However, equally present in the literature is that 1) substantiating and quantifying this claim is difficult, 2) designing focused and specific experiments is challenging, and 3) improving our understanding requires further research. One recent study by Walker, Brakefield, Morgan, Hobson, and Stickgold, (2002) examines motor skill learning in humans using a finger reaction test. For their study, 62 subjects (male and female, between 18 and 25), were divided into 5 groups and were trained on a task and retested twice with variations in the amount of wake and sleep time between the retests for each group (Walker et al., 2002). Their conclusions demonstrate that "sensorimotor skills may require post-training sleep for the optimal consolidation for learning and furthermore that this dependence may be sleep-stage specific" (p. 210). Hysing, Harvey, Linton, Askeland, and Siversten (2016) use the youth@hordaland-survey and grade point averages (GPA) of 7798 Norwegian adolescents between the ages of 16–19 to show an "association between sleep duration and sleep patterns and academic performance" (p. 318). Hysing et al. (2016) conclude that less time in bed (TIB), prolonged sleep onset latency (SOL), frequent waking after sleep onset (WASO), and poor sleep efficiency are "associated significantly with increased risk odds of poor academic performance" (p. 319). Mantua, Baran, and Spencer (2015) present further support for the active role in the consolidation of motor skill learning in the "visio-motor adaptation learning" of both young and older adult's (n = 123) using a mirror tracing task and conclude that sleep dependency is present in both populations (p. 593). The mirror tracing task was selected to evaluate both reaction time and accuracy and the specific memory stage of consolidation (Matua et al., 2015). In a complex, multifaceted experiment, Fogel et al. (2017) use actigraphy, sleep logs, questionnaires, PVTs, PSGs, and magnetic resonance images (MRI) to examine sleep spindles (bursts of brain activity seen with an EEG during sleep) and support the theory that motor skill memory consolidation is dependent on sleep even as we age. Each of these studies established the understanding that sleep affects cognitive performance for both young and older adults; the impact can be seen in both memory tasks and reaction

tasks, but further research is needed to better understand the practical implications of the impacts to military officers in training environments.

Although the role sleep plays in learning and memory is a well-established field of study, not all conclusions are universally accepted. In one of the more critical reviews pertaining to the connection between memory, learning, skill acquisition, and sleep Vertes (2004) recounts the historical exploration of the role of sleep in memory consolidation beginning in the 1960s and presents some findings to support the competing hypothesis that sleep actually does not play a role in memory consolidation. Based strictly on literature review (vice an actual experiment), Vertes (2004) draws the conclusion that insufficient sleep cannot be proven to affect consolidation of facts or procedural skills or enhancement of perceptual and motor skills and calls for more research to support or defend currently held beliefs. To refute the counterargument presented by Vertes (2004), Walker and Stickgold (2004) conduct a similar literature review on sleep-dependent memory processing and conclude that this area can be complicated because of differing opinions on how learning and memory occurs. The challenges in this field of research lie in the difficulty of forming a scientifically answerable question (i.e., the need to tie one specific type of learning task to be studied in the context of both sufficient and insufficient sleep) (Walker & Stickgold, 2004). In their very thorough literature review of human studies, consistently either sufficient sleep improves or insufficient sleep negatively affects motor learning, visual perceptual learning, auditory learning and that “learning and memory are dependent on processes of brain plasticity, and sleep-dependent learning and memory consolidation must be mediated by such processes” (Walker & Stickgold, 2004, p.128). Further discrediting Vertes (2004), Dijk, Derk-Jan, Winsky-Sommer, and Raphaelle (2012) use EEGs to capture the complex brain changes shown during various sleep stages that are implicated in memory consolidation. Additionally, Dijk et al. pointedly address the role that “deep sleep and rapid eye movement (REM)” contribute to neural network plasticity “which could help with the acquisition of new skills” (p. 4). Each of these prior studies are important because they show that although it is complicated and controversial, sleep plays an important role in any academic or skill acquisition environment and should be

taken into consideration when developing training plans. The current study uses daily PVT performance and some exam scores to explore the realistic and practical application of sleep and performance in a military academic and training environment to further this area of research.

E. PRIOR NPS SLEEP AND PERFORMANCE RESEARCH IN MILITARY EDUCATION AND TRAINING

The prior theses and dissertation work conducted at NPS pertaining to the impact of sleep and performance in a military training environment significantly shaped this study (Baldus, 2002; Andrews, 2004; Miller, 2005; Maynard 2008; Miller, Tvaryanas, & Shattuck, 2012; Gelpi, 2013). An overview of each prior study's methods, conclusions either supporting or failing to support the impact of insufficient sleep on performance, and study limitations helps to understand the design of the current research. Several of these studies use the Fatigue Avoidance Scheduling Tool (FAST) to focus on predicted performance. Unique to the current study is the use of the PVT. For clarity, Table 1 summarizes and compares the prior studies

1. Measuring and Modeling Performance

Prior NPS studies as well as the current one analyze performance through varying academic test scores and predicted performance. Specifically, three of the prior sleep and performance studies conducted at NPS explore the notion of predicted performance (Baldus, 2002; Miller, 2005; Maynard 2008). Although Baldus (2002) hoped to explore this area of research, the scope of the thesis did not allow for any detailed analysis. Using only a selected number of participants (those with the lowest mean sleep, median mean sleep, and highest mean sleep values), Andrews (2004) demonstrates degrading predicted performance (as both percentages and BAC equivalents) as a result of insufficient sleep. Building on the work done by both Baldus (2002) and Andrews (2004), Maynard (2008) explores sleep quantity, predicted performance, and actual performance but is unable to conclusively establish any significant correlations. In order to investigate the idea of predicted performance, each study uses modeling software known as the FAST. The current study seeks to better understand FAST, refine conclusions on the impact of

insufficient sleep quantity on predicted performance, and make use of a repeated standardized measure of performance known as a PVT.

a. Sleep, Activity, Fatigue, and Task Effectiveness Model (SAFTE) and the Fatigue Avoidance Scheduling Tool (FAST)

Beginning in 1996, the Department of Defense (DOD) worked with and several research and development corporations, to develop and improve a computer program that could be used to model predictive performance based on an individual’s sleep history (Hurs et al, 2004). As an Army colonel, Hursh headed up the sleep research groups at Walter Reed Army Institute of Research (WRAIR) prior to his retirement and moving to Science Applications International Corporation (SAIC). These key modeling developments gave leaders tools to optimize work or flight schedules and can be used to retrospectively analyze whether insufficient sleep could be a factor in a mishap. This work incorporated the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model. Figure 4 illustrates a schematic for SAFTE. The central focus of the model is the sleep reservoir (indicated by the purple rectangle). A linear performance use function models the minute by minute depletion in the reservoir as a result of wakefulness and accumulation as a result of sleep (Eddy & Hursh, 2001). The model allows the user to evaluate the impact of long work schedules, shift work, and poor sleeping conditions on things like cognitive effectiveness (Eddy & Hursh, 2001). Although the model proved useful, it was not user friendly, so further work was done to develop FAST. FAST is a Windows based computer program designed to implement the SAFTE model. A FAST user can either manually enter an individual’s sleep data or upload it from actigraphy data. As shown in Figure 5, the output of FAST is a visual depiction of the person’s predicted performance given their sleep history (Hartzler, Chandler, Levin, & Turnmire, 2015).

Figure 4. SAFTE Model Source: Eddy and Hursh (2001).

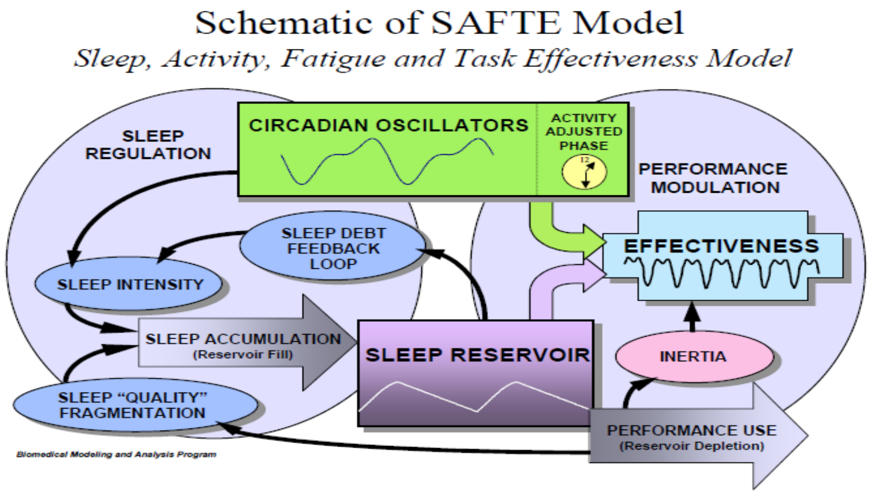
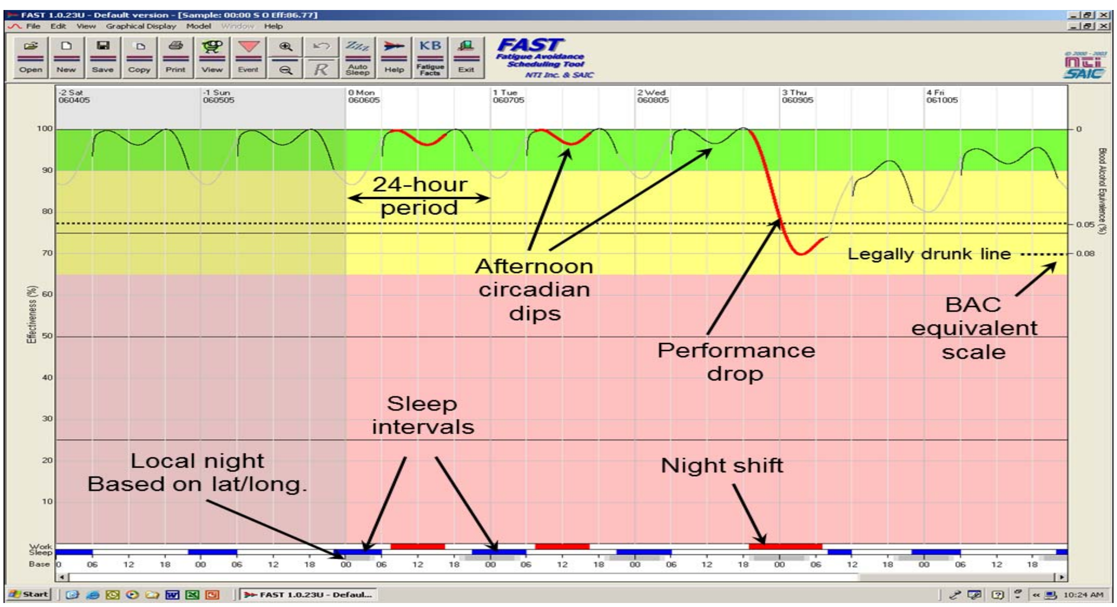


Figure 5. FAST Output. Source: Hartzler, Chandler, Levin, and Turnmire (2015).



b. *Psychomotor Vigilance Test or Task Sensitivity to Insufficient Sleep*

The earliest known study of the impact of sleep deprivation on an individual's performance is an experiment involving three participants in 1896 (Patrick & Gilbert, 1896). Throughout this 90-hour study, participants demonstrated decreased memory,

attention, and hand strength as well as increased body weight (Patrick & Gilbert, 1896). Since this early experiment, numerous studies have captured the impact of both chronic PSD and total sleep deprivation (TSD) on an individual's cognitive response times as well as physical performance. The most widely accepted practice for this type of reaction testing is the use of a PVT or a psychomotor vigilance task (Ambulatory Monitoring Inc. [AMI], n.d.b). A PVT is a task that records a participant's response time (RT) to a visual stimulus presented at a preset random inter-stimulus interval (ISI) range for a set duration of time (Basner & Dinges, 2011). The PVT is a reliable reaction time test that is both highly sensitive to sleep deprivation and has shown minor learning effects when taken repeatedly (Lim & Dinges, 2008; Basner, Mollicone, & Dinges, 2011). Although the standard 10 minute PVT (PVT-A) has been validated to objectively measure a participant's variability in alertness as a result of PSD or TSD, it is often too time consuming to be administered in an operational environment (Basner, Mollicone, & Dinges, 2011). More recently, a validated three minute version of the PVT (PVT-B) has now reduced the time needed for each trial (Basner, Mollicone, & Dinges, 2011). Furthermore, the platform for administering the standard 10 minute PVT (a laptop computer) is often too cumbersome in a realistic field or training environment outside of a laboratory. To implement PVT-B in a field setting, Ambulatory Monitoring Incorporated (n.d.a) developed the REACT software to be implemented into the Motionlogger wrist worn devices. Unlike all prior NPS sleep and performance studies conducted in a military training environments, PVT data can improve the understanding of daily functioning for each participant.

2. Unable to Demonstrate a Sleep and Performance Correlation

Of the prior NPS studies, two failed to draw substantial conclusions regarding insufficient sleep and its impact on performance (Baldus, 2002; Maynard 2008). Although Baldus (2002) demonstrated significant findings with respect to the levels of sleep obtained by participants, the performance data supplied for the study remains unanalyzed. The Maynard thesis (2008) featured a very small study subset for both exam scores and flight score (i.e., less than 30 for each metric). Furthermore, Maynard (2008) concluded that the study population was, in fact, not sleep-deprived. This conclusion

could possibly be a result of the increased emphasis placed on TRM during the WTI 2-06 course (Maynard, 2008). To eliminate the problems identified by both Baldus (2002) and Maynard (2008), this thesis uses a larger sample size, exam scores, and PVT data.

3. Degraded Performance as a Result of Insufficient Sleep

Three prior NPS studies conclude that a measurable improvement in performance reflects sufficient sleep quantity. Andrews (2004) examines the results of Navy recruit test scores over the course of three years. In years where recruits are afforded greater hours of sleep (8 hours vs. 6 hours), test scores are notably better. However, the conclusions in Andrews (2004) are based solely on the known schedules and the exam scores, no objective sleep data shows that recruits slept during rest hours given recruits and no there was no way to attest to the quality of sleep obtained (Andrews, 2004). With a large sample size (n = 209), Miller et al. (2012) uses actigraphy, psychological questionnaires, repeated physical fitness tests, marksmanship scores, and attrition rates on Army cadets at USMC who received a greater sleep quantity and better sleep quality had improved mood as well as performance compared to those in a control group who did not. However, the performance metrics gathered in this study (physical fitness scores and marksmanship scores) are not established as being highly sensitive to sleep deprivation and the study does not use standardized vigilance tests like PVTs or attempt to obtain predicted performance via FAST (Miller et al., 2012). Extending the prior work, Gelpi (2013) analyzes 57 Marines over the course of a 16-day study of performance on amphibious vehicles. Gelpi (2013) concludes a positive relationship exist between sleep quantity and quality and performance by testing marksmanship, physical fitness performance (obstacle course), and cognitive testing. The current work seeks to extend these findings by combining actigraphy data, exam scores, PVT data, and standardized questionnaires.

Table 1. NPS Sleep Research During Military Training and Education.

Study	General Information				Sleep			Performance				Results/Conclusions
	Location	Study Dates	Duration	Sample Size (N=)	Actigraphy	Activity Logs	Questionnaires /Surveys	FAST	PVT Laptop	PVT Actiwatch	Other	
Baldus (2002) United States Navy Enlisted Training at RTC Great Lakes	Great Lakes, Michigan	April to June 2002	~3weeks	31	Yes	Yes	No	No	No	No	Recruit Military Knowledge Tests	Students alloted 8hrs of sleep but actual sleep is far less; female recruits received slightly more sleep on average than their male counterparts; sleep quality and performance not analyzed
Andrews (2004) Sleep Regimen and Performance in United States Navy (USN) Recruits	Great Lakes, Illinois	2000, 2001, 2003	9 weeks (each year)	2597	No	No	No	No	No	No	Recruits Military Knowledge Test; ASVAB	Military knowledge test scores increased over the three years, possibly attributed to increased sleep but there were other environmental improvements; objective sleep data not collected
Miller (2005) United States Military Academy (USMA) Study	West Point, New York	July 1, 2004 to August 15, 2004	30 days	79	Yes	No	Yes	Yes	No	No	None	Study populaion is sleep deprived; recruits received approx. 2hrs, 6mins less than prior to Combat Basic Trainng (CBT); sleep was not impacted by other demographic factors; FAST applied for maximum, median, and minimum sleep values results demonstrated degredation in predicted performance
Maynard (2008) Marine Aviation Weapons and Tactics School One(MAWTS-1)/ WTI 1-06	Yuma, Arizona	September 16, 2005 to October 29, 2005.	44 days	20	Yes	Yes	No	Yes	No	No	Exams; (limited) flight scores	Compared to prior baseline study population not sleep deprived; no significant correlations between sleep quantity/quality and student performance, FAST predicted effectiveness was not significantly correlated with flight or exam scores
Miller et al. (2012) Adolescent Sleep-Wake Patterns: Army Basic Combat Training (BCT)	Fort Leonard Wood, Missouri	June 2009 to April 2010	~9 weeks	392 (209 Intervention & 183 Control)	Yes	No	Yes	No	No	No	Basic rifle marksmanship scores; General Technical (GT) from ASVAB; physical fitness scores	Increased sleep had small but measurable influence on various indicators of trainee performance; improved sleep quality (as a result of phase-delayed sleep schedule) established but impact not analyzed
Gelpi (2013) Sleep on the Performance of Marines Following Exposure to Waterborne Motion	Pelican Point, Red Beach, Camp Pendleton, California	2013	16 days	57	Yes	Yes	Yes	No	No	No	Laser Marksmanship Training System (LMTS); Obstacle Course, Cognitive Battery Test	Sleep history did have an impact on performance; a circadian effect was observed throughout the testing period, as sleep quantity and quality increased; performance also increased

III. METHODOLOGY

A. PURPOSE

The desires of the MAWTS-1 leadership, the expertise of the Crew Endurance Team at NPS, and the construct of previous sleep and performance studies conducted in military training and education environment informed the methodology selected for this thesis. The nature and duration of the study, a collaborative team arranged and received approval for this study through the NPS Institutional Review Board (IRB) process. This study varies from prior studies in both the number of participants and the variety of platforms used to gather information. The study employed questionnaires, wrist worn actigraphy, activity logs, PVT, several exam scores, and attempted to employ FAST, throughout the WTI 2-16 course to measure the quantity and quality of the sleep and performance of participants.

B. SLEEP TEAM, INSTITUTIONAL REVIEW BOARD (IRB) PROCESS, AND INFORMATION MANAGEMENT

Undertaking a study of this size and duration required extensive collaboration between MAWTS-1 and NPS. Table 2 details the original research team members for this study. Members of the MAWTS-1 staff (physically located in Yuma, AZ, but not in participants' chain of command) and the principal investigators in Monterey, CA shared roles and responsibilities. Members of the team communicated primarily via email and teleconference with two major in-person meetings (at the beginning and end of data collection) to synchronize procedural efforts as well as exchange collection devices and data. A detailed IRB application containing all members of the team was routed through the NPS approval process. The MAWTS-1 research team members handled the recruitment, consent, instruction on the use of actigraphy and PVT devices, device distribution, data download, and day to day interaction with participants. Appendix A is the Recruitment Brief given to the WTI 2-16 students. The consent forms for participation in the study are in Appendix B. Data cleaning, scoring, and analysis were conducted at NPS and serve as the focus of this thesis. Appendix E is the complete study calendar.

Table 2. Research Team.

Name	Title	Dept	Role/Responsibilities
Dr. Nita Lewis Shattuck	Associate Professor	Operations Research(OR)/Human Systems Integration (HSI)	Overarching study development and approving authority
Major Rachel Gonzales	USMC OR Thesis Student	OR	Student Investigator
Dr. Panagiotis Matsangas	Post-doctoral Associate	OR/HSI	Study development, data collection and analysis
Tristin Baxter	Research Assistant	OR/HSI	Data Collection and analysis
Major Matt Bohman	USMC Aviation Operations Analyst	MAWTS-1	Data collection and analysis
Lieutenant Eric Litzberg	USN Aero Medical Safety Officer	MAWTS-1	Data collection and analysis

C. PARTICIPANTS

Both MAWTS-1 staff (instructors and supporting staff) and WTI 2-16 students (both aviators and non-aviators) participated in this study. This participant group differed from the original 2008 Maynard thesis which focused on a small group of WTI students who were all aviators (Maynard, 2008). Participation was completely voluntary and could be terminated at any time. Table 3 summarizes rank and gender contributions to the study. Figure 6 shows the distribution of ages for all participants. The average age of participants was 32.8 years (+/- 4.4 years). Table 4 is a summary of participants by department and staff (either student of staff).

Table 3. Participant Gender and Rank.

Gender	Civilian	Enlisted	Officer	Total
Female	2	1	7	10
Male	0	25	94	119

Figure 6. Participant Age.

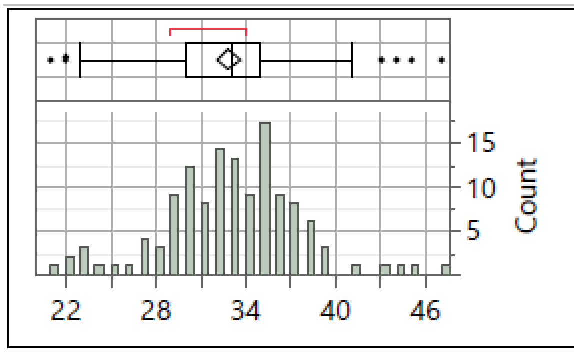


Table 4. Participant Type.

Department	Staff	Student	Total
Air Officer Department (AOD)	3	8	11
Assault Support Division (ASD)	36	18	52
Aviation Development, Tactics & Evaluation (ADT&E)	2	0	2
Aviation Ground Support (AGS)	3	3	6
Command, Control, & Communications (C3)	14	9	23
Ground Combat Division (GCD)	4	7	11
Headquarters (HQ)	5	0	5
Tactical Aviation (TACAIR)	15	4	19
Total	82	49	131

Participants were asked to wear one of two types of actigraphic wrist worn devices (actiwatches): either Respironics Spectrum or Ambulatory Monitoring Incorporated (AMI). The AMI watches will be discussed further in the Actigraphy portion of this section. Unfortunately, the data collected from the Respironics watches (41 participants from the AGS, C-3, and GCD divisions) could not be analyzed because of device malfunction and data corruption caused by defects in the Respironics software. While the participation and questionnaires gathered from those participants wearing the Respironics watch is included in this study, objective sleep data cannot be included at this time. For future studies, one device brand should be used for the study and data should be downloaded, at regular intervals, on a daily basis if possible. Table 5 shows the number and brand of watches issued. Participant #138 provided no information about their status as a student or staff member.

Table 5. Actiwatch Brand Issuance.

Watch Brand	Unknown	Staff	Student	Total
AMI	1	59	30	90
Respironics	0	21	20	41
		80	50	131

WTI 2-16 was the second WTI course offered during fiscal year 2016. Students checked into the course on Sunday, 6 March 2016, and graduated 24 April 2016. Table 6 represents the key dates in the WTI 2-16 course.

Table 6. WTI2-16 Major Course Events.

Phase	Key Event	Date
	Student Check-in	6-Mar-16
Academic	Inventory Exam	7-Mar-16
Academic	Generics Exam	10-Mar-16
Academic	TRM Module	10-11 Mar 16
Academic	Commons Academic	12-Mar-16
Academic	Commons Exam	18-Mar-16
Academic	Specifics Academic	18-Mar-16
Flight	Flight Phase Begins	28-Mar-16
Flight	Specifics	28-Mar-16
Flight	Commons	4-Apr-16
Flight	Major Evolutions	11-Apr-16
Flight	FINEX	18-Apr-16
	Graduation	24-Apr-16

1. Questionnaires

Participants completed three questionnaires over the course of the study: an initial pre-study questionnaire, a second questionnaire after completing the instructional phase of the school (midpoint of WTI), and a final post-study questionnaire. Each questionnaire required approximately 20 minutes to complete. The pre-study questionnaire consisted of questions about demographics and basic personal information on each participant. All three questionnaires contained questions from the following validated surveys: Epworth Sleepiness Scale (ESS), the Pittsburgh Sleep Quality Index (PSQI), the Morningness-Eveningness Questionnaire (MEQ), the Profile of Mood State (POMS), and the Insomnia

Severity Index (ISI). Appendix C contains examples of all the questionnaires administered.

Dr. Murray W. Johns (1998) developed the ESS in the early 1990s as an inexpensive, self-administered survey that uses eight different scenarios to score an individual's level of daytime sleepiness. Table 7 is a list of the ESS questions used to determine whether participants have subjective indications of excessive daytime sleepiness. For each scenario based question, the participant must rank between 0 and 3 (highest) the tendency to doze off (Johns, 1991; Johns, 1994; Johns, 1998). The final score for the ESS is calculated using the sum of all eight questions, and represents the participant's Average Sleep Propensity (ASP) (Johns, 1991; Johns, 1994; Johns, 1998). ESS scores range from 0 to 24. A higher ESS score indicates a higher propensity to doze off when the average individual would not (Johns, 1991; Johns, 1994; Johns, 1998). This method has been demonstrated to be highly reliable when given to the same subject several times over the course of a few months and has been used in several studies pertaining to sleep apnea, and narcolepsy (Johns, 1991; Johns, 1994; Johns, 1998). An ESS score of 10 is referenced as the highest value considered for a normal amount of daytime sleepiness in clinical trials (Johns, 1991 & Johns, 1994).

Table 7. ESS Questions. Adapted from Johns (1994).

ESS Questions
Sitting and reading
Watching TV
Sitting in active in a public place (e.g. a theater or a meeting)
As a passenger in a car for an hour without a break
Lying down to rest in the afternoon when circumstances permit
Sitting and talking to someone
Sitting quietly after a lunch without alcohol
In a car, while stopped for a few minutes in traffic

The complete PSQI was introduced in the late 1980s and is a validated, 19-question survey used to evaluate the sleep quality of an individual (Backhaus, Junghanns, Broocks, Riemann, & Hogan, 2002). The PSQI is also a self-rating questionnaire ranging from 0 to 21 total points that are broken into the following categories: sleep quality, sleep

onset latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction with poor sleep quality suggested at scores > 5 (Backhaus et al., 2002). For the purposes of this study, four questions were asked that required user input followed by 15 questions regarding usual sleep habits. See Appendix C for a complete list of questions.

Horne and Ostberg developed the MEQ the mid-1970s which contains 19 questions, each ranked on a 4 point scale. The sum of the scores, ranging between 16 and 86, is used to determine if a person self identifies as one of three types: evening-type (E-type, scores ≤ 41) neither-type (N-type, ≥ 42 and ≤ 58), or morning-type (M-type, ≥ 59) (Baehr, Revelle, & Eastman, 2000). Table 8 summarizes the MEQ scores. For the purposes of this study, the MEQ was only administered during the first questionnaire session.

Table 8. MEQ Scores. Adapted from Baehr, Revelle, and Eastman (2000).

Type Assignment	MEQ Score
Evening (E-type)	16-41
Niether (N-type)	42-58
Morning (M-type)	59-86
Total	16-86

Heuchert and McNair developed the POMS to be used in environments where participant's moods might fluctuate as a result of changes in the environment (2003). The POMS assesses six affective states: Tension-Anxiety (POMS T), Depression-Dejection (POMS D), Anger-Hostility (POMS A), Vigor-Activity (POMS V), Fatigue-Inertia (POMS F), and Confusion-Bewilderment (POMS C) and grades them on a 65 point adjective rating scale (McNair, Lorr & Droppleman, 1992). Put simply, the POMS questionnaire, which takes a person between 3 to 7 minutes to complete, attempts to assess transient and distinct mood states (Shacham, 1983). The six affective states are calculated with scores from various subsections and an aggregate Total Mood Disturbance (TMD) scores is the sum of POMS T, POMS D, POMS A, and POMS F minus POMS V. When multiple questionnaires are administered over a time, an increasing TMD score is reflective a degrading or negative trend in mood. Table 9

summarizes the scoring for the POMS affective states and TMD. See Appendix C for a complete example of the POMS administered for this study.

Table 9. POMS Scoring Breakdown. Adapted from McNair, Lorr, and Droppleman (1992).

POMS Affective States	Range of Scores
POMS T (Tension and Anxiety)	0 to 36
POMS D (Depression)	0 to 60
POMS A (Anger-Hostility)	0 to 48
POMS V (Vigor- Activity)	0 to 32
POMS F (Fatigue)	0 to 28
POMS TMD (Total Mood Disturbance)	-32 to 200

Morin, Belleville, Bélanger, and Ivers (2011) provide details regarding the scoring of the ISI. Morin et al. outline that the ISI assesses an individual's level of insomnia through the following dimensions: 1) severity of sleep onset, 2) sleep maintenance and early morning awakening problems, 3) sleep dissatisfaction, 4) interference of sleep difficulties with daytime functioning, 5) noticeability of sleep problems by others, and 5) distress caused by the sleep difficulties. Each item is ranked from 0 to 4 with 0 being no presence and 4 indicating a very severe problem. Table 10 is the interpretation of the total score. Appendix C contains a complete example of the ISI questions used for this study.

Table 10. ISI Score Interpretations Adapted from Morin et al. (2011).

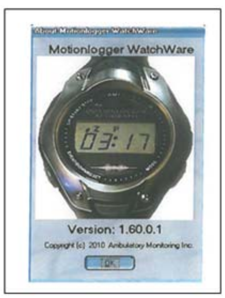
Interpretation	ISI Score
Absense of Insomnia	0-7
Sub-threshold Insomnia	8-14
Moderate Insomnia	15-21
Severe Insomnia	22-28

2. Actigraphy

Over 30 years of research outline the benefits and validity of utilizing actigraphy to objectively quantify the amount and quality of sleep for an individual. Actigraphy

devices are commonly worn on participants' non-dominant wrist and provide researchers and participants a less invasive and more affordable tool to assess activity than the industry gold standard, PSG (Blackwell et al., 2008). Today, the commercial market is flooded with options for individuals to purchase such devices. The U.S. military is increasingly interested in their use, seeking to find the perfect combination of validation and practicality that can be employed in field and training environments. For the purposes of this study, participants were asked to wear the Motionlogger Watch from Ambulatory Monitoring Incorporated (AMI). Using a "state of the art tri-axial accelerometer," the Motionlogger has been validated against the standard PSG and has been determined to have acceptable accuracy for a healthy adult population (n.d.b). Figure 7 shows an image of the Motionlogger used for this study along with device specifications.

Figure 7. AMI Motionlogger Actiwatch. Adapted from AMI (n.d.b).



Motionlogger Specifications
Weight: 65 grams (with battery)
Dimensions: 5.5 x 4.5 x 1.8
Non-Volatile Memory: 2Mb
Mode: Zero Crossing Mode (ZCM)
Battery Life: 30-Days (1-minute data collection epochs)
Water resistant: Up to 50m of static pressure

Prior to being issued to a participant, each Motionlogger watch was inspected for battery life and initialized using local date and time. The mode of operation selected for this study was Zero Crossing Mode (ZCM) which measures the frequency of movement in 1-minute epochs (AMI, n.d.b). Actiwatches were worn for the duration of the WTI 2-16 course (approximately seven weeks). In most cases, watches were collected after 30 days to check the batteries, download data, and reinitialize them. For a few participants, watches had to be replaced. Aside from individual watch malfunctions, participants complained that the watches were bulky and inconvenient, limited in their functionality (no stop watch function, ability to modify date/time, ability to synchronize, not waterproof, etc.).

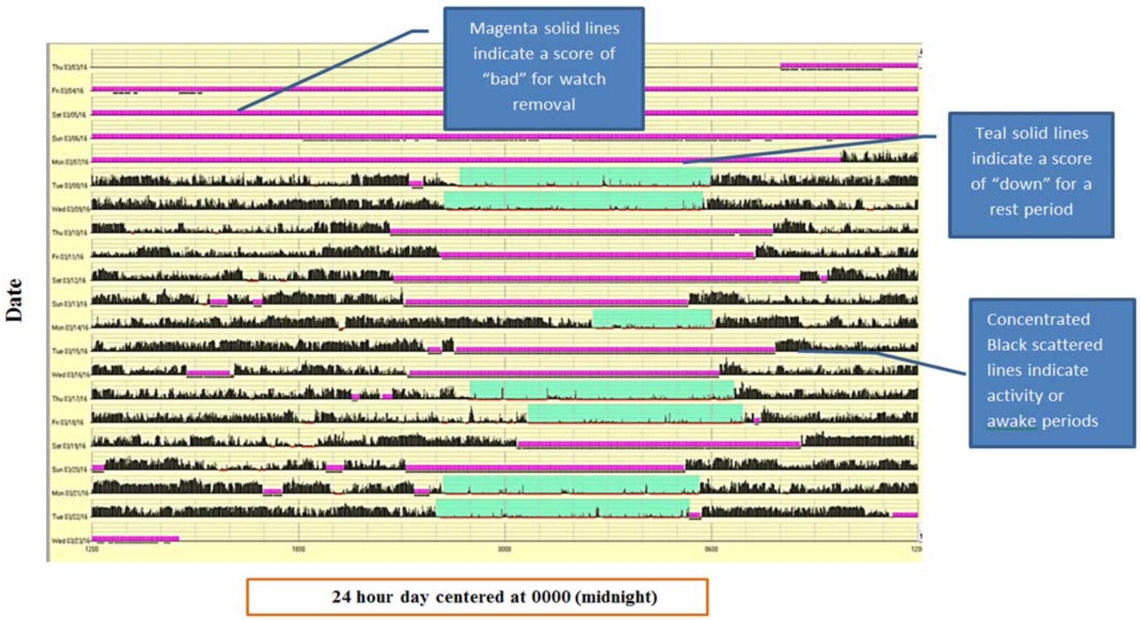
The amount of data collected varied day to day between individual participants based on their dedication and commitment to the study. With the actigraphy data downloaded from the watch, it was read into the ActionW 2.7 software. Figure 8 shows an example of the downloaded actigraphy from a single participant in the form of an actigram (AMI, n.d.b).

Within the actigram, each horizontal segment of data represents a single, 24-hour day. The current view is set with 1200 (noon) at the beginning of the segment and 0000 (midnight) in the middle. Figure 8 contains 18 full days of data with partial days displayed for the first and last day. Each file can be saved with participant identification and the date the information was downloaded. One recommendation that will be discussed later focuses on the need to identify early any other software program researchers want the actigraphy to be read into for analysis. This is a critical consideration with a large sample size because some software programs require the actigraphy files to be saved in a particular format in a specific file name. Colors displayed in the actigram convey information regarding sleep and activity. The wave-like, black lines represent an individual's activity as activity counts within that specified one minute epoch. Larger and or more heavily grouped lines represent periods of high activity, whereas, smaller and less frequent lines represent periods of low activity or rest. In order to scrub the raw actigraphy file, a manual process was used to identify periods of rest and watch removal. When possible, participant activity logs were used along with the researcher's judgement to identify the rest (or "down") periods in the bright teal and the watch removal (or "bad") periods in the bright magenta color. Unless an activity log indicated that a participant had specifically taken a nap, a period of "no activity" was scored as "bad." Each file can take approximately 10 to 15 minutes to conduct this scrubbing process.

Once scrubbed, the actigraphy was then scored using the Action 2.7 software. This software makes use of the algorithm developed by Cole-Kripke as it is best suited for use in adult populations (ActiGraph, n.d.). In 1992, researchers developed and optimized the Cole-Kripke algorithm to correctly distinguish sleep periods from non-sleep periods 88% of the time and able to be used with a variety of devices (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992). The algorithm weights the average of each of the

previous four minutes, the current minute, and the next two minutes, and identifies those that should be considered “sleep” or “wake.” The algorithm then uses a set of rules to correct for obvious discrepancies (Cole et al., 1992).

Figure 8. Actigram. Adapted from AMI (n.d.).

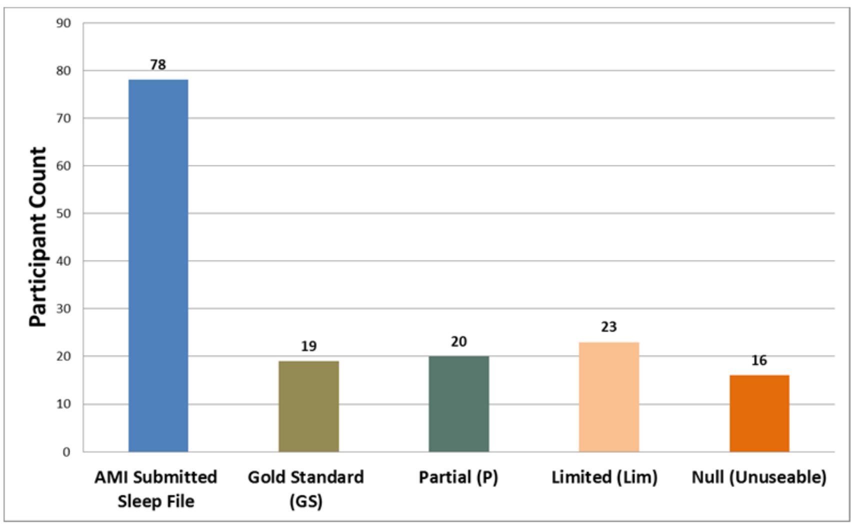


The actigraphy gathered was then categorized into four types based on subjective and objective information. Table 11 summarizes each of four categories of AMI sleep data (Gold Standard (GS), Partial (P), Limited (Lim), and Null (Null)). Null AMI sleep files could not be used for any conclusive analysis. Lim files showed when a participant began and ended participation but had too many gaps or missing information to be of further use. The GS and P sleep files contained the best quality sleep data and provided the source for the most thorough analysis. It is important to note that the categories of GS, P, Lim, and Null were assigned according to the quality of the data, not the quality of the sleep of the individual participant. Two participants AMI files (#175 and #194) showed that the participants only wore the watches at night and failed to wear them during the day. As this was inconsistent with all other AMI files, these were labeled as Lim and not considered for further evaluation. Figure 9 is a graphical depiction of the number of submissions of the AMI sleep files broken down by data quality category.

Table 11. AMI Sleep Data Quality Categories.

File Category	Abrev.	Objective Criteria	Subjective	How it was captured
Gold Standard	GS	>=30 days of useable sleep data, <=3 separate gaps in data	Limited visible variability in sleep patterns, gaps are easily quantified, appeared to stick with the study for the majority of time	Entered as "GS", full raw data copied, detailed effort made to capture any gaps
Partial	P	13<= days of useable sleep data <30, <=3 separate gaps in data	Limited visible variability in sleep patterns, gaps are easily quantified, appeared to stick with the study about half the time	Entered as "P", full raw data copied, detailed effort made to capture any gaps
Limited	Lim	5>=sleep days <13, >=3 gaps in data	Some useable sleep episodes but highly variable or too many gaps to quantify	Entered as "Lim", only captured start/end dates and times and number of sleep episodes, did not copy raw files or gaps
Null	Null	<5 days Sleep Data, >3 separate gaps in data	Nothing useable	Marked as "null", nothing recorded or captured

Figure 9. AMI Sleep Data Quality Submissions.



3. Activity Logs

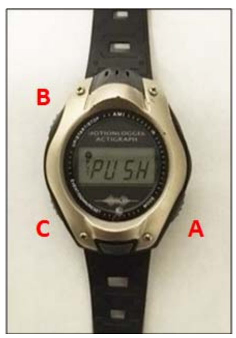
Each participant was asked to complete an individual activity log and to annotate when the watch was removed, the approximate time they rested each day, and their off duty time. Fifty total activity logs were collected (30 pertaining to those participants wearing the AMI watch). In general, most of the activity logs provided little information and were often incomplete. Appendix D is an example of the activity log provided to participants.

4. Performance

a. PVT

For the purposes of this study, participants were asked to perform one PVT-B with the backlight setting off, twice a day. Each PVT had a total duration of three minutes with inter stimulus intervals (ISI) of 1000 to 4000 milliseconds (between 1 and 4 seconds). Participants were asked to take the first daily test prior to 1200 each day (AM test) and the second after 1800 (PM test) for the duration of the study. Figure 10 shows the PVT-B displayed on the Motionlogger as seen by each participant. To perform the test, participants were asked to press any of the buttons A, B, or C as quickly as possible when they saw the target word "PUSH" appear on the watch face. Times were recorded in milliseconds (ms) for each valid response

Figure 10. Motionlogger PVT.



To extract an individual's performance on the PVT-B, the REACT software was used to create text files of the results. Figure 11 shows an image of a raw PVT extracted from a single participant and a single PVT-B test.

Figure 11. Raw .pvt File for Single Trial.

```
"PVT DATA"
"STUDY: ", "WTI2-16"
"SLEEPY PRE, POST TRIAL: ",1,1
"E. INITIALS:", "AMI"
"S. INITIALS:", "AMI"
"S. ID NUMBER:", 1234
"TRIAL NUMBER:", 1
"TRIAL DATE:", "03/07/16"
"TRIAL TIME:", "0948"
"ISI MIN (ms):", 2000
"ISI MAX (ms):", 10000
"TRIAL LENGTH (s):", 180
"TASK:", "V"
"HAND: ","R"
"PVT S/N:", 5207
20000,  27.7
2784,  36.5
20000,  56.3
683,  64.0
301,  69.3
368,  72.8
322,  79.1
210,  83.3
279,  95.7
233,  100.9
428,  109.3
262,  120.6
268,  124.9
289,  132.2
221,  142.5
276,  150.8
258,  157.1
285,  161.4
231,  168.6
193,  173.8
0,  0
```

There are several output metrics from PVT data that can provide useful insight. Figure 12 demonstrates the variety in the use of these metrics used throughout the literature (Basner & Dinges, 2011). A few examples of interesting metrics for the PVT-B are the number of lapses (those responses that took greater than 500ms to respond to the target), median and mean Response Times (RT) across trials, errors of omission (when a target is completely missed), the variability of the RTs, and the measurement of "time-on-task effect" also referred to as 1/RT or speed (Lim et al., 2008). In a sleep deprived individual, one expects to see a slowing of overall PVT RTs, a greater number of omission errors, and errors of commission (Basner, Mollicone, & Dinges, 2011). Furthermore, these authors found that reciprocal metric mean (1/RT) has superior statistical properties. They recommend that mean RT and median should be avoided because of their tendency to introduce statistical bias (Basner & Dinges, 2011). In general, responses for the three minute PVT-B tend to be faster overall than for the 10 minute PVT-A (Basner and Rubinstein, 2011). Metrics for evaluating PVT-B remain consistent with those of the standard PVT with the added consideration that lapses are better evaluated as those responses that took longer than 355ms (vice those greater than 500ms) (Basner, Mollicone, & Dinges, 2011). For this study, a RT of less than 100ms was recorded as a False Start (FS). A response time greater or equal to 355ms was

recorded as a lapse. Lapses greater than 500ms were also recorded for potential use in future studies. The use of valid responses greater than or equal to 100ms and less than 355ms as well as reciprocal response time (1/RT) as valid output metrics is supported by several prior studies (Basner & Rubinstein, 2011, Baser & Dinges, 2011; Basner, Mollicone, & Dinges, 2011). Other selections for the PVT output metrics supported by the literature should be considered for future work.

Figure 12. Frequency of PVT outcome come metrics.
Source: Basner and Dinges (2011).

Table 1—Frequency of PVT outcome metrics reported in 141 journal publications published since 1986[1]

Outcome	Frequency
Number of Lapses[2]	66.7%
Mean RT[3]	40.4%
Mean 1/RT	30.5%
Fastest 10% RT	29.8%
Median RT	28.4%
Slowest 10% RT	19.9%
Slowest 10% 1/RT	12.8%
Number of False Starts	9.2%
Fastest 10% 1/RT	5.0%
Lapse Probability[4]	4.3%
Other	23.4%

[1]The 141 articles are the result of a Thomson ISI search on "psychomotor vigilance" in title, abstract, or keywords of peer-reviewed articles published since 1986 performed on 30 April 2010.
[2]Lapses were most commonly defined as response times > 500 ms or ≥ 500 ms, although individual studies used different definitions.
[3]RT = response time
[4]Lapse probability is usually calculated as the number of lapses divided by the number of valid stimuli.

b. Exams

One additional measure of performance that pertained specifically to the WTI 2-16 students were three exams given during the academic phase. During the first week of class all students took the same generic inventory exam. The second exam was issued during the generics portion and tested students on their understanding of similar aviation platforms or areas of aviation support most similar to their own. The final written exam was given during the commons portion of the curriculum and was a detailed examination

of each student's knowledge pertaining to their particular aircraft or area of support. In order to maintain the academic integrity of the exams copies could not be provided. The scores of the students who elected to participate in the study were collected with the intent to examine any relationships between exam scores and sleep quantity and quality.

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IV. ANALYSIS

A. STUDY PARTICIPATION

Study participation considers the sleep data contributed by participants with sleep data for the entire study—the "gold standard" or GS—and participants with only partial sleep data for the study—the "partial" or P group. Figure 13 displays the individual sleep data contributions of each participant for the duration of the course. Figure 14 and Figure 15 show aggregate sleep contributions and PVT contributions by date respectively. The red lines in Figures 14 and 15 represent major events in the curriculum. Figures 13, 14, and 15 illustrate that a major gap occurred in the middle of the curriculum (between the Academic Phase and the Flight Phase) for individual sleep data, total sleep episodes, and PVT compliance, respectively. During this three day time period, little to no objective data were collected because the actiwatches were off wrist while being downloaded. Additionally, once the watches were returned and the flight phase began, those participants categorized as P stopped wearing their actiwatches and no longer contributed sleep data (with the exceptions of #167 and #136).

Figure 13. Individual Participant Sleep Data Over Time.

Figure 14. Total Sleep Episodes by Date.

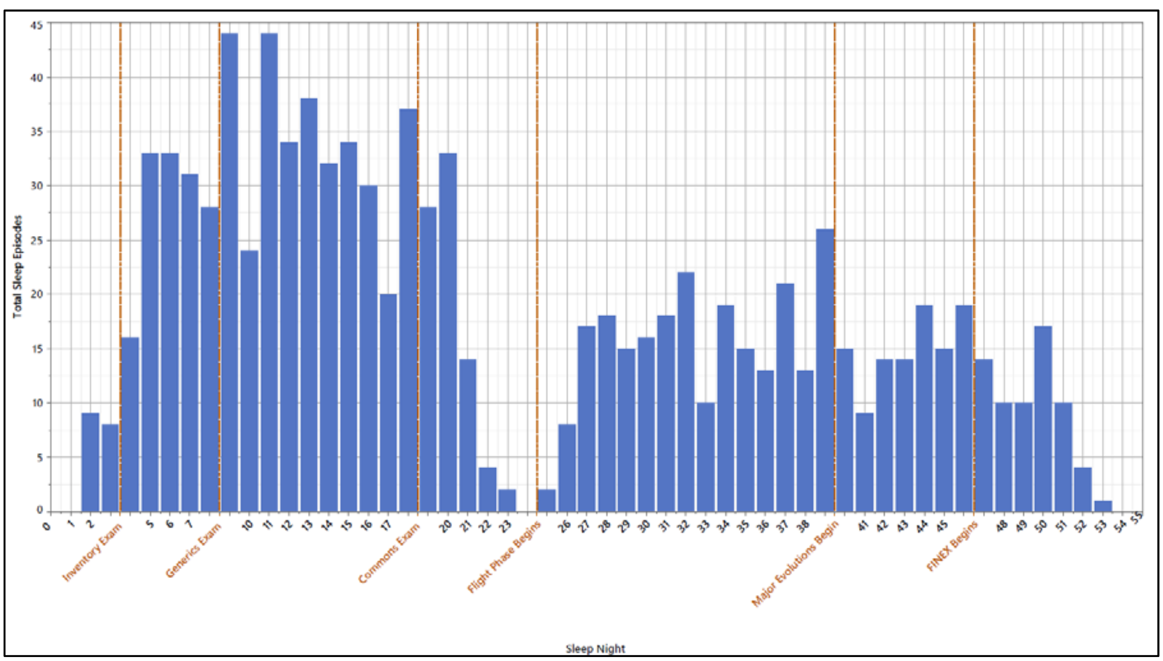
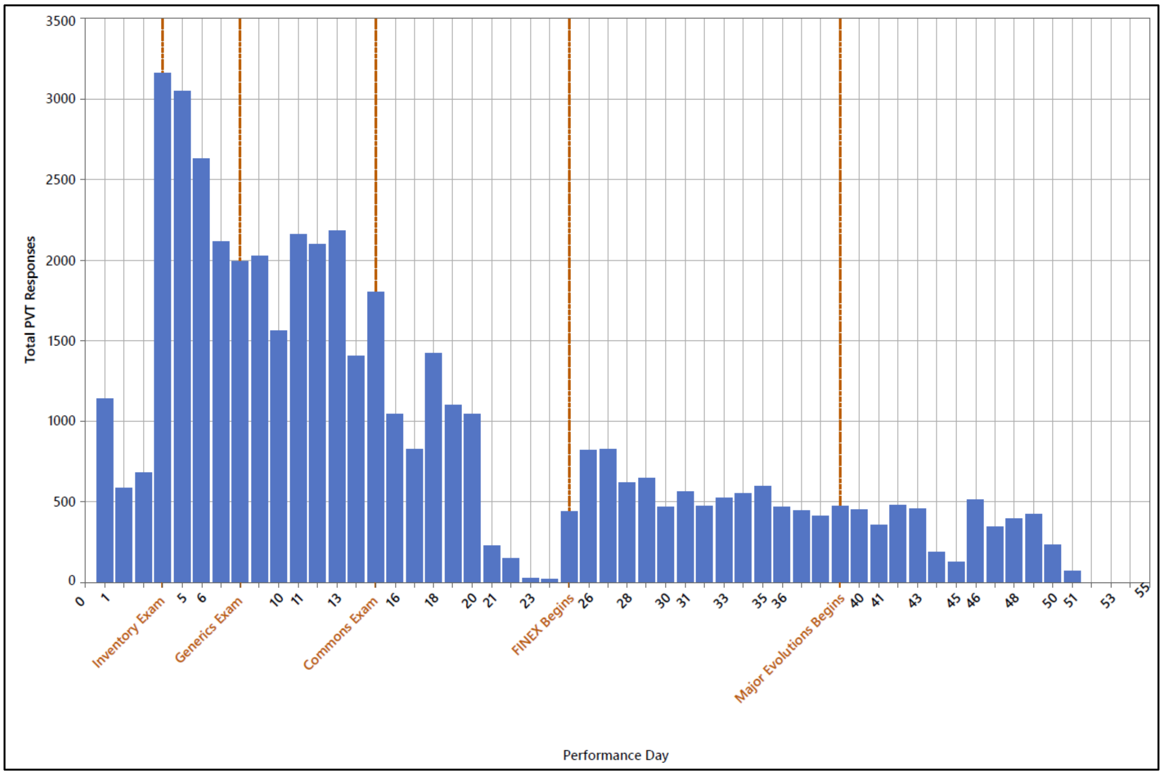


Figure 15. PVT Compliance.



Similar conclusions regarding study participation were gained from the questionnaire submission. Initially, 129 participants submitted the pre-study questionnaire. This number fell to 91 by the second administration and to 82 by the final administration. From the initial questionnaire to the final submission, there was a 36% drop in participation over the seven-week period.

The desire to graphically visualize and compare phases motivated the decision to apply “phase days” and “phase nights.” Appendix F contains the phase night and day assignments used throughout the study group. “Academic Phase Day 1” corresponds to 03/03/2016 and “Flight Phase Day 1” corresponds to 03/28/16. “Academic Phase Night 1” corresponds to the night of sleep that began the evening of 03/04/16 and ended the morning of 03/05/16.

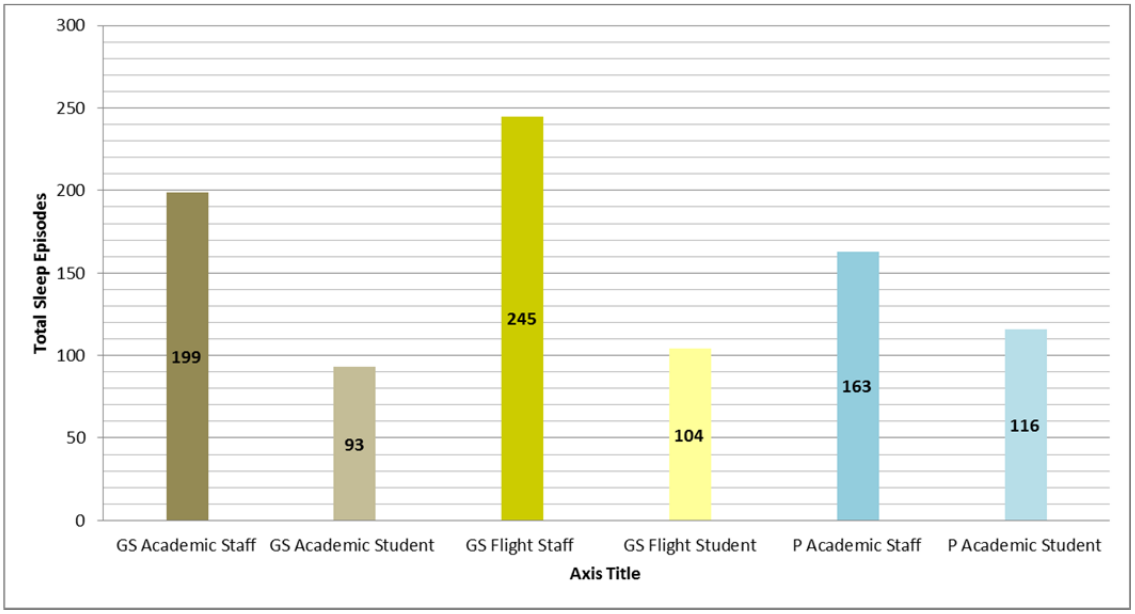
B. SLEEP DATA CLEANING

Analysis of the sleep data gathered for this study requires an understanding of the operating environment for WTI 2-16. Both academic instruction and practical field applications were conducted during typical daytime working hours (approximately 0700 to 1800 daily). Low-light or evening operations were conducted during the flight phase but typically concluded no later than 2300. Study participants did not stand watch and were not employed in shiftwork. Additionally, there were few opportunities for most participants to take naps during regular work days (Monday through Saturday). Each of these factors is considered when scoring the raw sleep files. Unless specifically annotated in an activity log, participants were not considered to have slept outside of the window from 2000 to 0600. For the initial detailed analysis, only the sleep files of the participants who were categorized as GS and P were examined. Twenty-three participants with limited data or "Lim" and 16 participants with missing sleep data or "Null" were excluded from further evaluation due to insufficient data.

Microsoft Excel was used to concatenate information from several different spreadsheets pertaining to sleep quantity, demographics, performance data, and to combine individual sleep episodes into single nights of sleep (Microsoft, 2010). The sleep files for one unique participant (#155) demonstrated signs of regular napping and this was supported by activity log entries. As a result, this participant displayed a greater amount of variability in sleep patterns than to all others and was removed. Two additional sleep episodes were removed, one for participant #110 and one for participant #191, because they registered as a single minute of sleep duration. Calculations were made utilizing JMP software for an individual's mean and median nightly sleep duration.

Figure 16 illustrates the sleep data contributions of both the GS and P groups by phase and status. The category of GS Flight Staff provided the greatest number of sleep episodes for review, while the smallest number of contributions was from the categories of GS Academic Student and GS Flight Student. These limitations constrict the insights that can be provided about students throughout the course.

Figure 16. Sleep Episode Contributions by Group Phase Status.



Testing was done to determine if there was difference in sleep quantity or quality between the GS and P groups. The null hypothesis tested was that there was no difference in sleep duration or efficiency between the two groups. The intent of this test was to see if a decrease in sleep quantity, or much lower sleep efficiency for P participants could help explain the reduction in participation. Figure 17 shows the distributions of participant's mean sleep duration and mean sleep efficiency for the two groups. For mean sleep duration, the data for both groups appear to be unimodal and normally distributed. For mean sleep efficiency, the data for both groups appear to be bimodal and skewed left. One- way analysis of these metrics between the two groups, shown in Table 12, reveals no statistically significant difference in mean sleep duration. While a statistically significant difference exists between mean sleep efficiency (p-value of .05), from a practical standpoint, this difference is <2%. Normal sleep efficiency is considered 85% and anything >90% is considered very high (Breus, 2013). The conclusion from this comparison is that there is no difference in the sleep quantity and quality between the GS and P participants. As a result of this conclusion, the remaining sleep analysis focuses on the data provided by the GS group since it is greater in quantity and spans the duration of the WTI 2-16 course.

Figure 17. GS vs. P Comparisons.

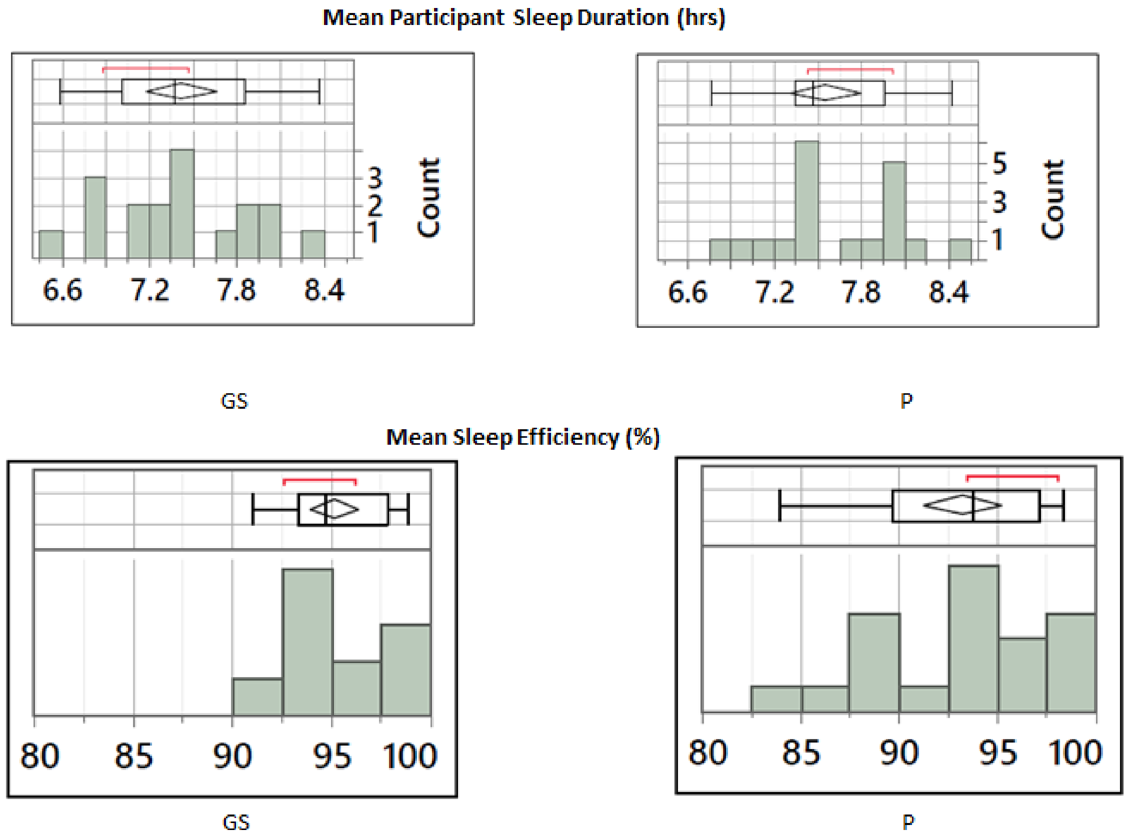


Table 12. GS vs. P Statistical Comparison.

	Sleep Data Quality Group	Max	Min	Mean +/- SD	Median	t-test (p-value)
Sleep Duration (Hrs)	GS (n=18)	8.36	6.95	7.42+/-.49	7.38	0.79
	P (n=20)	8.42	6.27	7.55+/-.52	7.47	
Sleep Efficiency (%)	GS (n=18)	98.86	91.01	95.14+/-2.45	94.74	0.05
	P (n=20)	98.36	83.89	93.24+/-4.25	93.72	

Summary statistics of the two sleep data quality groups were determined using each individual's mean value for sleep and efficiency. This comparison included 18 GS participants. #158 was later removed from the GS group for the remaining sleep analysis. Using a one-way ANOVA t-test, there is statistically significant differences in sleep efficiency between the GS and P groups, p-value of 0.05. However, this equates to a 1.9% difference and should not be considered a practical difference. Both GS and P groups had highly efficient scores.

C. SLEEP ANALYSIS

The analysis of sleep data collected from the WTI 2-16 course was examined with respect to sleep duration (quantity) and sleep efficiency (quality) scores. Two additional

variables were created to explore how participants' nightly sleep duration varied from typical night's sleep on any particular specific date or portion of the curriculum. The "delta median sleep" variable was constructed by subtracting a current night's sleep duration from that participant's overall median sleep duration. Equation (1) is the calculation used for "delta median sleep." A negative value indicates a decrease in a participant's sleep duration on a particular night from his or her median. Various combinations were examined to determine if there were any significant differences during particular portions of the curriculum, between the two phases, and between the two status groups of students and staff. Particular attention was paid to the amount and quality of sleep received prior to major events such as an exam or the major evolutions of the flight phase.

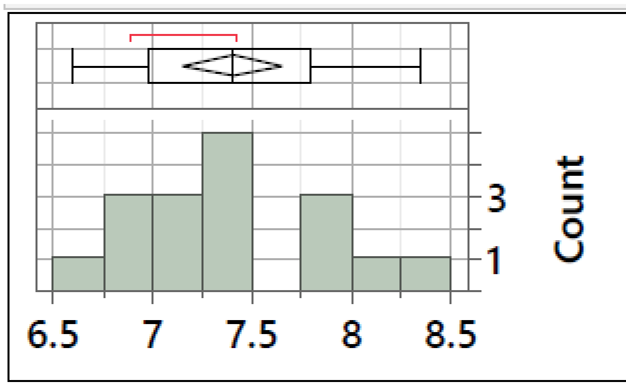
$$\boldsymbol{Delta\ Median\ Sleep = Sleep\ Duration - Median\ Sleep} \qquad (\mathbf{1})$$

A total of 17 participants, 11 staff members and 6 students, contributed sufficient sleep data in both the academic and flight phases to be examined for the remaining sleep analysis. Participant #158 was originally categorized as a GS participant, but was removed because sleep data was collected only in the academic phase.

1. Sleep Duration

Based on the individual mean sleep durations of the 17 GS participants, mean participant sleep duration for WTI 2-16 was 7.40 (7 hours and 24 minutes) with a standard deviation of 0.48 (29 minutes). Figure 18 shows the distribution of participant's mean sleep duration ranges between 6.59 hours and 8.36 hours.

Figure 18. Distribution of Participant's Mean Sleep Durations (Hrs) for WTI 2-16.

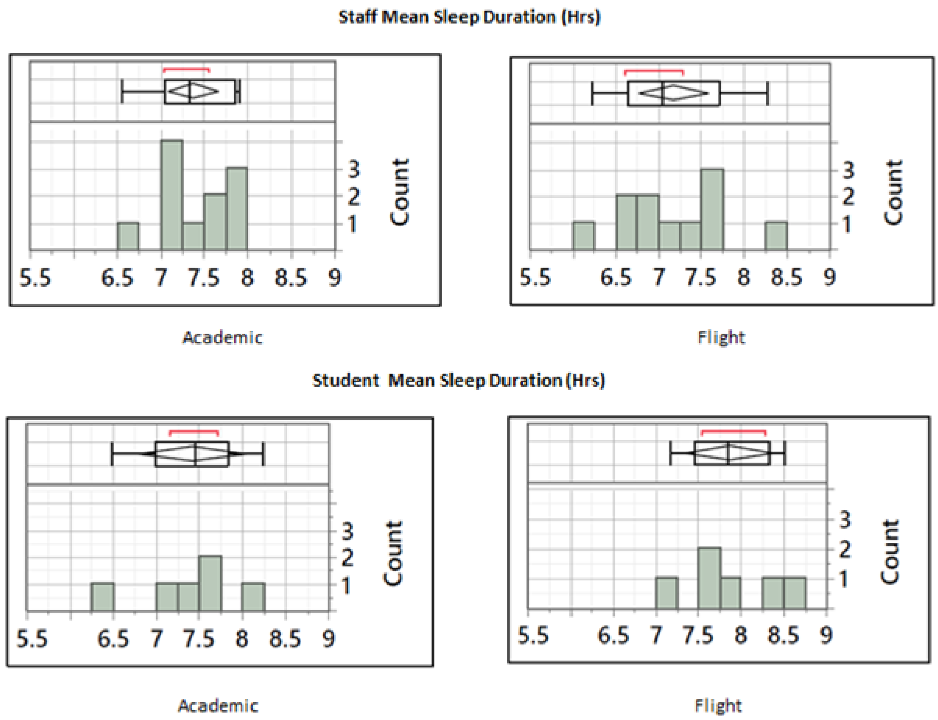


Participant's mean sleep duration for the course is based on the GS 17 participants (11 staff and 6 students) who provided the most sleep data in both the academic and flight phases.

One of the research questions the study sought to address was if at any point within the curriculum, either students or staff became chronically fatigued. In general, Figure 18 supports the conclusions that throughout the entire course, study participants were permitted rest opportunities (between 6 and 8 hours) and that they typically used them. The next layer for consideration was a comparison of the two phases of the curriculum. The null hypothesis states there is no difference in sleep duration between the academic phase and the flight phases. Figure 19 shows the distribution and summary statistics of sleep between the two phases and the two statuses. A within-subjects (n = 17), matched pairs analysis (t-test) confirmed there was no statistical difference in mean sleep duration between the two phases (p-value = 0.84).

A paired t-test comparing students to staff in the academic phase showed no statistical significance between the two groups (p-value = 0.88). A paired t-test comparing students and staff in the flight phase was statistically significant at the 95% confidence level with a p-value of 0.026. This difference suggests that students receive on average .69 hours (41 minutes) more sleep than staff during the flight phase. Although this value is based on a small sample size (n = 17) and two unequal groups (11 staff members and 6 students), from a practical standpoint, it does show that student participants were afforded sufficient rest opportunities for and recovery during the flight phase of training and that it was slightly more than the staff received.

Figure 19. Mean Sleep Distributions and Summary Statistics for WTI 2-16 by Phase and Status.



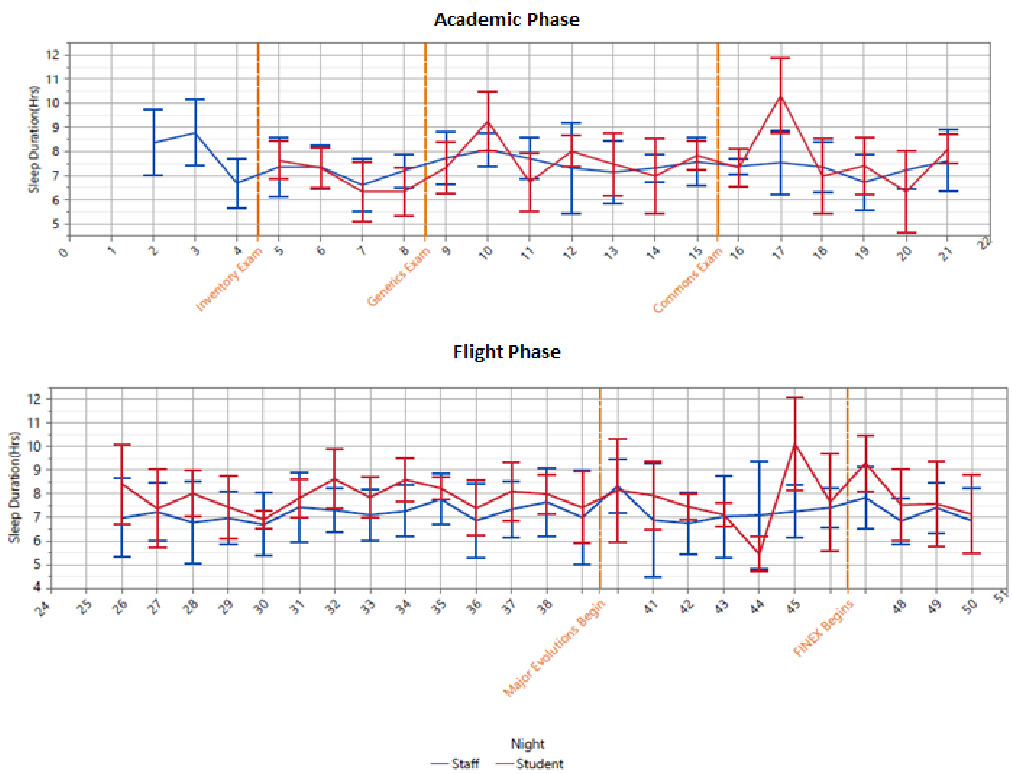
Status	Phase	Min	Max	Median	Mean	Std Dev	N
Staff	Academic	6.56	7.90	7.33	7.37	0.44	11
	Flight	6.24	8.27	7.05	7.17	0.61	11
Student	Academic	6.49	8.24	7.45	7.41	0.59	6
	Flight	7.17	8.51	7.84	7.86	0.49	6

Mean sleep duration for the course is based on the GS 17 participants (11 staff and 6 students) who provided the most sleep data in both the academic and flight phases. Within-subjects, matched pairs analysis (t-test) showed no difference in sleep duration between the two phases (p-value of 0.84). A paired t-test comparing students to staff in the academic phase confirmed no statistical (p-value of 0.88). A paired t-test comparing students and staff in the flight phase was statistically significant at the 95% confidence level with a p-value of .026

Sleep duration was also considered on a night-by-night basis. Figure 20 displays sleep duration by night along with a mean fit line and single standard deviation error bars for both staff and students. See Appendix F for the date that corresponds to each night of sleep. Actigraphy sleep episodes were consolidated so that any sleep occurring from 2000 to 0600 was associated with a single night of sleep. Of interest in Figure 20 is Night 17,

which stands out as a night when students received a greater amount of sleep than usual. This night of sleep is for a Saturday evening into a Sunday morning (a day with no classes). Additionally, Nights 44 and 45 appear unusual compared to other nights. Night 44 is a Friday night and appears to have been associated with less than usual sleep for students and Night 45 is a Saturday night and appears to have been more than usual sleep.

Figure 20. Duration (Hrs) for Students and Staff by Night.



Nights represent the night in which sleep began. Actigraphy sleep episodes were consolidated so that any sleep occurring from 2000 until 0800 was associated with a single night of sleep. Each error bar is constructed using 1 standard deviation from the mean.

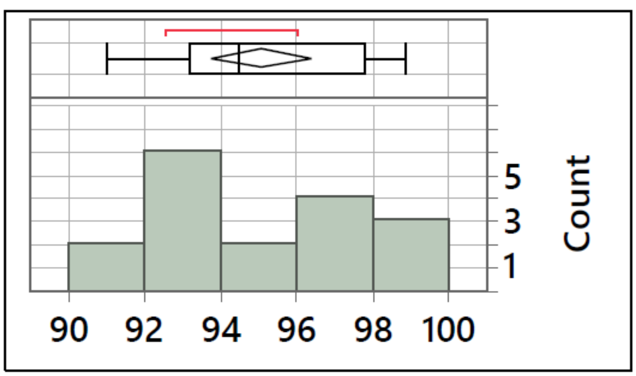
Finally, the variability in sleep duration for each GS participant was explored. Appendix G contains the individual box plots of each GS participant's median sleep delta grouped by status. There were no overarching trends or concerns apparent from this analysis. A more detailed examination into each of these participants and their particular billets and staff responsibilities could provide better insights into sleep pattern variations.

Based on the individual mean sleep durations of the 17 GS participants, mean participant sleep duration for WTI 2-16 was 7.40 (7 hours and 24 minutes) with a standard deviation of 0.48 (29 minutes). Within-subjects comparisons between the academic and flight phases failed to reject the null hypothesis and supported the assertion that there was no difference. A paired t-test comparing students and staff suggests that students receive on average about 41 minutes more sleep than staff members during the flight phase. Descriptive analysis of the night-by-night variations in sleep duration suggests that students may be slightly more fatigued at the end of the academic phase and the end of major evolutions, but that they continue to take advantage of rest and recovery time offered at the end of these periods.

2. Sleep Efficiency

Mean participant sleep efficiency for the course was 95.06% with a standard deviation of 2.52%. Figure 21 shows the distribution of sleep efficiency for the course which ranges between 91.00% and 98.96%. In general, study participants averaged highly efficient sleep.

Figure 21. Distribution of Mean Sleep Efficiency (%) for WTI 2-16.



Mean sleep efficiency for the course is based off of the GS 17 participants (11 staff and 6 students) who provided the most sleep data in both the academic and flight phases.

A more detailed analysis of the sleep efficiency was conducted to determine if there were any major concerns regarding sleep quality throughout the curriculum. Similar to the analysis conducted on sleep duration, this analysis began with a comparison of

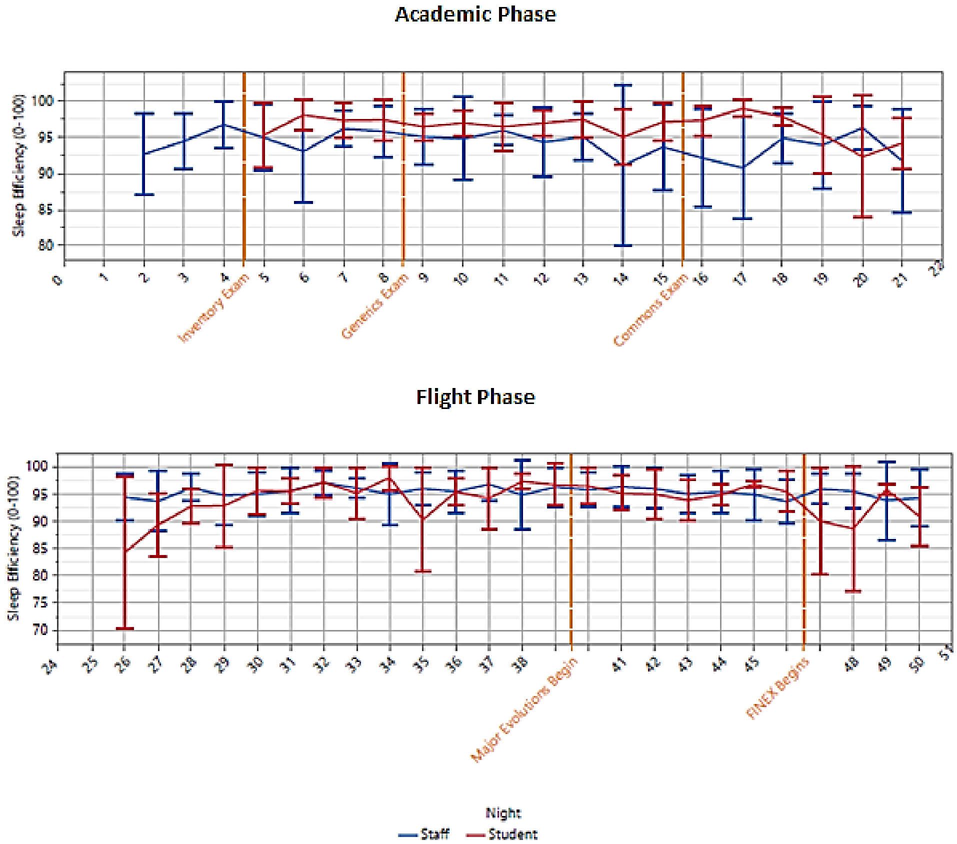
efficiency between the academic phase and the flight phases and started with the assumption of no difference between the two phases. A within-subjects ($n = 17$), matched pairs analysis (t-test) confirmed no statistical difference between the two phases (p-value = 0.79).

Further inquiry was made to compare the sleep efficiency of the two status groups. The null hypothesis assumed that there was no significant difference in the sleep efficiency of these two groups. A paired t-test of students vs. staff showed no difference between the sleep efficiency of the two groups in either the academic phase (p-value =0.23) or the flight phase (p-value = 0.35). Within-subjects comparison between phases for the students was not conducted due to the small sample size ($n = 6$).

Sleep efficiency was also considered on a night-by-night basis. Figure 22 displays sleep efficiency by night along with a mean fit line and single standard deviation error bars for both staff and students. Although efficiency appears to be more variable during the FINEX portion of the flight phase, there are no specific instances of concern.

On average, the WTI 2-16 study participants receive 95% sleep efficiency, which is considered very high. There were no differences between the academic and the flight phase nor were there differences between students or staff members. There was no particular day or event that negatively impacted sleep efficiency.

Figure 22. Efficiency (%) for Students and Staff by Night.



Nights represent the night in which sleep began. Actigraphy sleep episodes were consolidated so that any sleep occurring from 2000 until 0800 was associated to a single night of sleep. Each error bar is constructed using one standard deviation from the mean.

3. EXAMS AND SLEEP

Once the sleep data were categorized by data quality group and the students were separated from the staff, only 14 participants had test scores that could be examined with respect to sleep. No participants failed the Commons Exam and only three participants scored less than 90%. Furthermore, the Generics Exam test scores were only provided for four of participants in this group and all achieved greater than 90%. As a result, no further analysis was conducted on either the Commons or the Generics Exam scores. Table 13 summarizes the test scores received for those participants who contributed sufficient sleep data during the academic phase.

Table 13. Exam Scores.

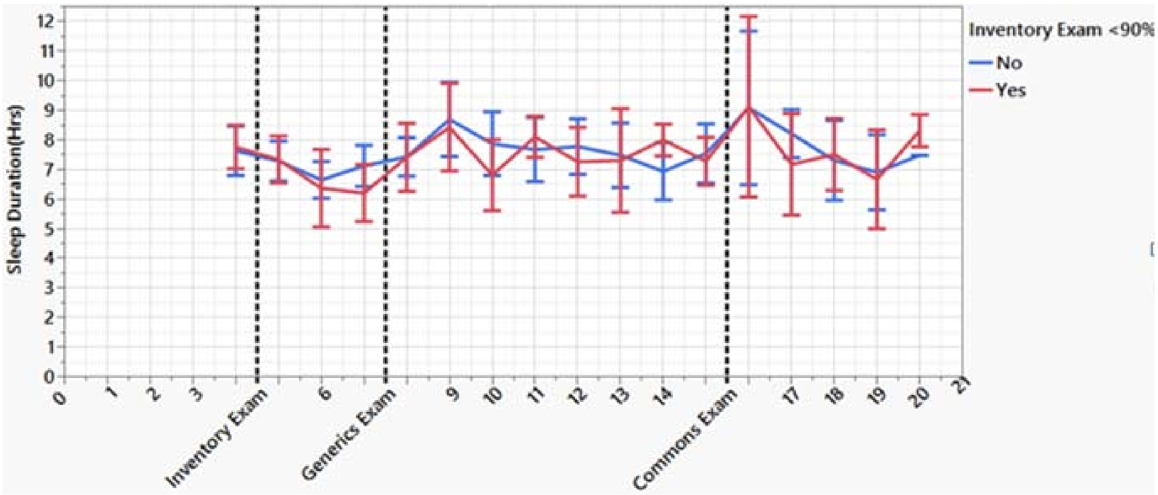
Participant ID	Data Quality Category	Exam		
		Inventory	Generics	Commons
157	Gold Standard (GS)	88	96	NA
201	Gold Standard (GS)	80	84	NA
205	Gold Standard (GS)	78	84	NA
206	Gold Standard (GS)	92	94	NA
240	Gold Standard (GS)	88	90	NA
244	Gold Standard (GS)	94	94	94
108	Partial (PGS)	96	94	NA
198	Partial (PGS)	86	92	98
202	Partial (PGS)	84	90	NA
207	Partial (PGS)	90	98	100
208	Partial (PGS)	98	96	94
209	Partial (PGS)	92	92	94
211	Partial (PGS)	90	88	NA
233	Partial (PGS)	96	96	NA

a. Failed and Lower Scoring Exams

A failed exam score is anything less than 80%. Of the students who contributed sleep data during the Academic Phase of training, only one individual received a failing grade on the Inventory Exam (participant #205 with a score of 78% identified in red box in Table 13). Unfortunately, there was insufficient sleep data to determine if this failed grade was affected by insufficient or poor quality sleep. Additionally, this participant received less sleep prior to the Generics Exam and performed above 80%. Further review of this participant's demographic information revealed that he or she was not a USMC officer which may have been a factor in failure of the Inventory Exam.

A new variable was created to identify students who scored less than 90% on the inventory exam. Figure 23 shows the comparison of those students who scored below 90% vs those who scored above 90%. Insufficient sleep data prior to the Inventory Exam prevents definitive conclusions about how sleep duration or efficiency may have impacted that score.

Figure 23. Sleep Duration (Hrs) for Inventory Exam Score Comparison.



Further hypothesis testing of the exam scores is not possible due to the limited number of test scores provided and the diversity of the students between various departments and sleep data quality groups. A comparison of test score differences between the Inventory exam and the Generics exam is not possible because not all students take the same Generics Exam and the tests cover different material.

D. PVT PERFORMANCE DATA

Figure 24 shows how each PVT response was categorized and considered for analysis. The decision to declare responses ≤ 100ms as False Starts (FS) as well as to exclude responses ≥ 3,000ms is well documented in the literature. The metric of a lapse ≥ 355ms is currently accepted for use on the PVT-B. Lapses ≥ 500ms are provided as reference and consideration for future work.

Figure 24. Breakdown of PVT Response Types.

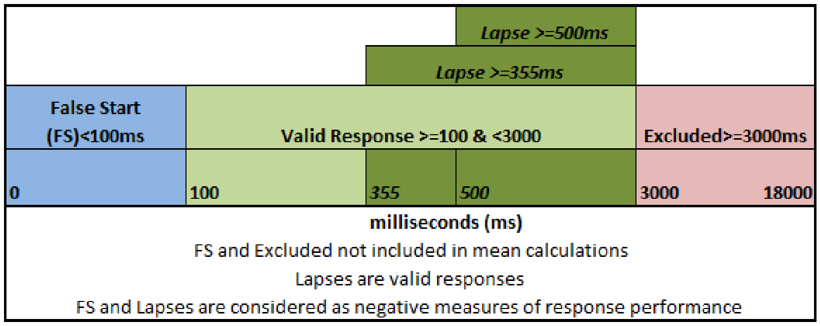


Figure 25 displays the composition of all individual responses. Figure 26 displays the composition of valid responses. Appendix H gives an inventory table of all PVT responses collected. The table breaks down both the raw numbers for each response type as well as their corresponding percentage of total responses and/or valid.

Figure 25. Individual PVT Response Composition.

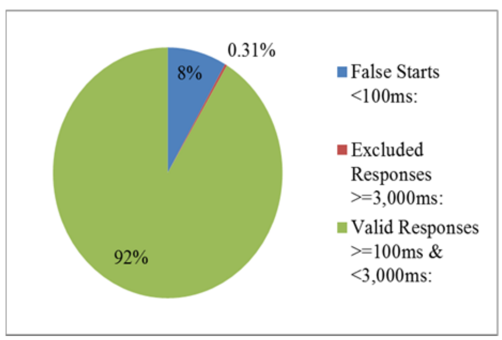


Figure 25 displays all individual PVT responses collected with the exception of those that were ≥3,000ms. The 92% of valid responses represented in green is further broken down in Figure 26.

Figure 26. Valid PVT Response Composition.

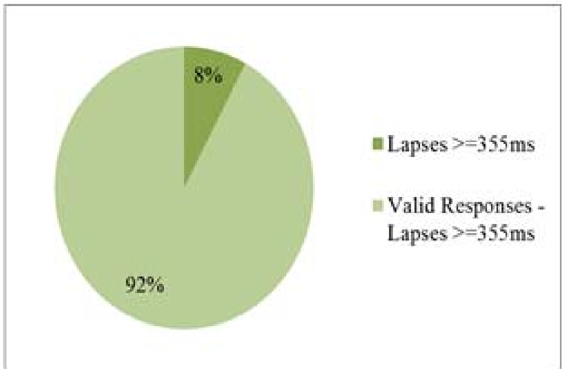


Figure 26 is an analysis of all the valid PVT responses collected. The entire image is a subset of the green portion seen in Figure 25.

E. PVT ANALYSIS

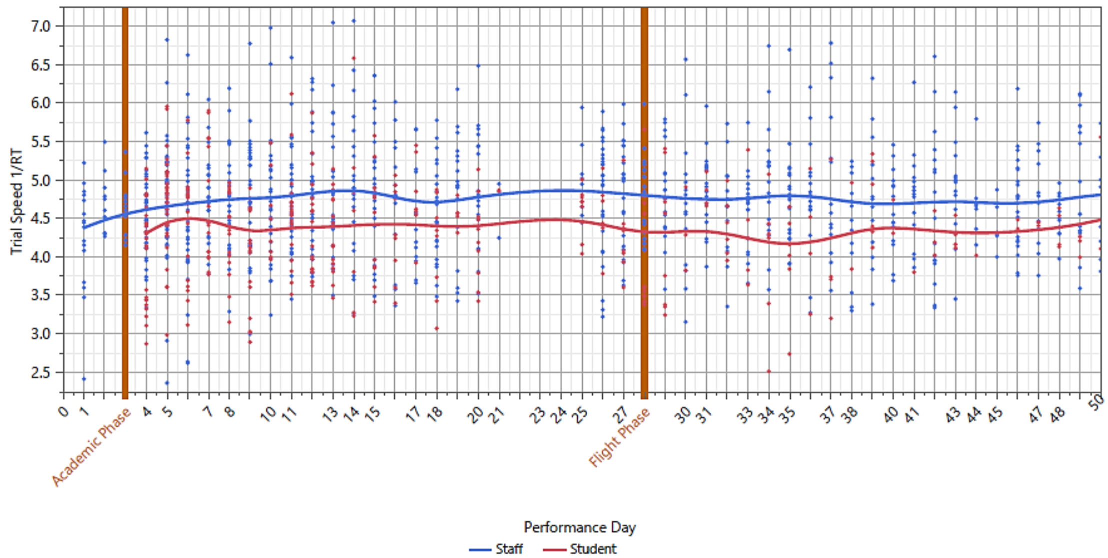
The feature that distinguishes this study from others done in a military training environment is the collection and incorporation of PVT data. As such, documenting and understanding the detailed data cleaning process in critical to follow-on work. The PVT output metric being analyzed dictates the method by which the data is sorted and cleaned. Appendix J outlines the step-by-step process used for this specific analysis. By detailing the steps used for this analysis, they may become improved and automated for increased efficiency in future work. This process was conducted primarily in JMP and Microsoft Excel.

The literature supports the use of the output metric of reciprocal reaction time (1/RT) as a measurement for response speed (Basner & Dinges, 2011; Basner et al., 2011). This metric is calculated by taking a valid RT, multiplying by 1,000 and taking the reciprocal (Basner & Dinges, 2011; Basner et al., 2011). RTs are reported in milliseconds (ms) and 1/RT is reported as 1,000/seconds (1/s). Larger values for 1/RT indicate faster speeds.

Figure 27 shows 1/RT values by performance day for both students and staff for the duration of WTI 2-16. A visual inspection of Figure 27 communicates that the staff is consistently faster than students and that there is no noticeable difference between phases for either group. Figure 28 shows the distribution of each participants mean 1/RT for the

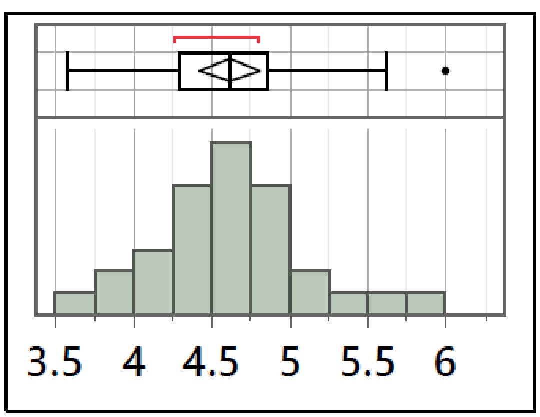
course which ranges between 6.00 and 3.43. Table 14 shows the PVT 1/RT summary statistics for WTI 2-16 and supports that in general the staff appears to be faster than the students.

Figure 27. 1/RT by Performance Day.



Performance Days represent the day in which a PVT was taken. PVT trials were consolidated so that any trial occurring from 0500–2359 was assigned to a single Performance Day. Each error bar is constructed using one standard deviation from the mean. The smoother applied to Figure 30 uses a cubic spline with lambda 0.05 and x-values are standardized.

Figure 28. Distribution of Mean Participant Trial Speed (s).



The distribution of mean participant trial speed (s) for WTI 2-16 is based on each of the 31 participants' mean speed for their respective trials.

Table 14. PVT 1/RT Summary Statistics.

	Status	Max	Min	Mean +/- SD	Median
Phase	**All (n=31)**	6.00	3.43	4.61(+/-.52)	4.62
Academic	**Students (n=10)**	5.13	3.43	4.33 (+/-.49)	4.33
	Staff (n=21)	5.99	3.86	4.74 (+/-.51)	4.78
Flight	**Students (n=10)**	4.71	4.71	4.19 (+/-.37)	4.31
	Staff (n=21)	6.00	3.75	4.82 (+/-.53)	4.77

Tests for statistical significance were conducted to compare PVT speed performance between the two status groups and two phases. Wilcoxon rank sum tests were performed to compare the speed of the two status groups. The comparison between staff and students in the academic phase produced a p-value of 0.03 and the comparison in the flight phase produced a p-value of 0.04; both of which are statistically significant at the 0.05 level. Table 15 is a summary of the statistical comparisons conducted between the two status groups and suggests that the staff consistently performed faster than the students. Although statistically significant differences were seen between the two status groups, from a practical standpoint, the range of all mean reciprocal reaction times as shown in Table 14, was between 3.43 and 6.00. When converted back to milliseconds, the average reciprocal reaction time ranged between 160ms and 300ms which is an acceptable range of responses and thus limits the amount of insight that can be gained from just this analysis. Additional within-subjects, matched pairs analysis was done to compare the difference in speed between the academic phase and the flight phase. These results are shown in Table 16 and did not reveal any significant change in speed between the two phases.

More detailed descriptive analysis was conducted to compare the day-to-day changes in response speed. Figure 29 shows this analysis and supports the earlier claim that staff generally had faster reciprocal reaction times than the students.

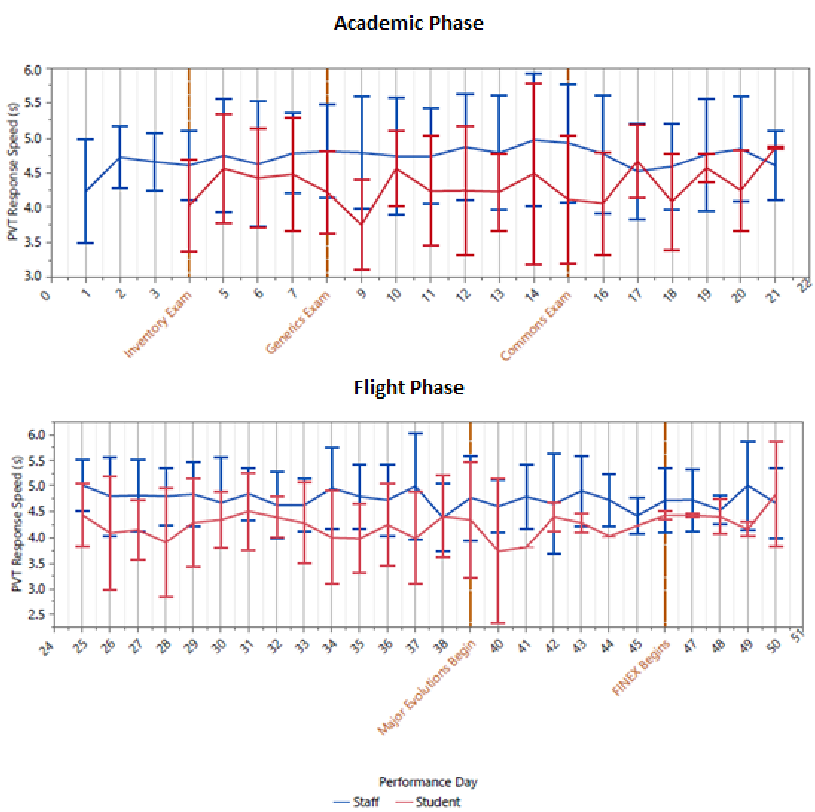
Table 15. Statistical Test Comparisons of 1/RT for the Students and Staff.

Status Comparison (Wilcoxon)		
	Z	p-value
Academic	2.22	**0.03**
Flight	2.02	**0.04**

Table 16. Statistical Test Comparisons of 1/RT for the Academic and Flight Phases.

Phase Comparison (Within-subjects Matched Pairs)		
	t-ratio	p-value
Students (n=10)	1.09	0.29
Staff (n=21)	-1.28	0.23

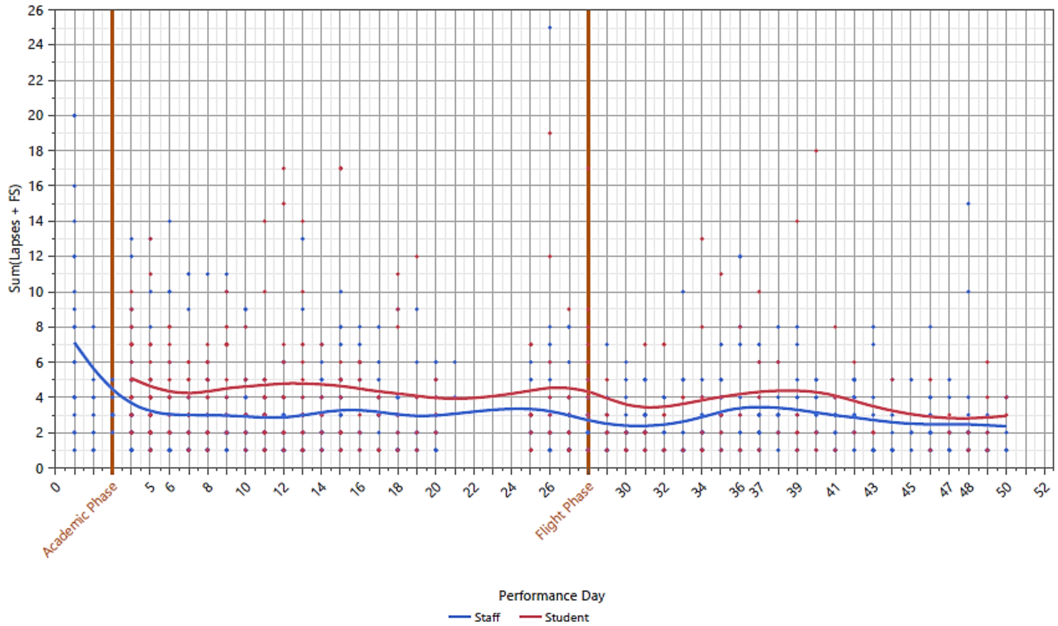
Figure 29. PVT Speed (s) for Students and Staff by Day.



Performance Days represent the day in which a PVT was taken. PVT trials were consolidated so that any trial occurring from 0500–2359 was assigned to a single Performance Day. Each error bar is constructed using one standard deviation from the mean.

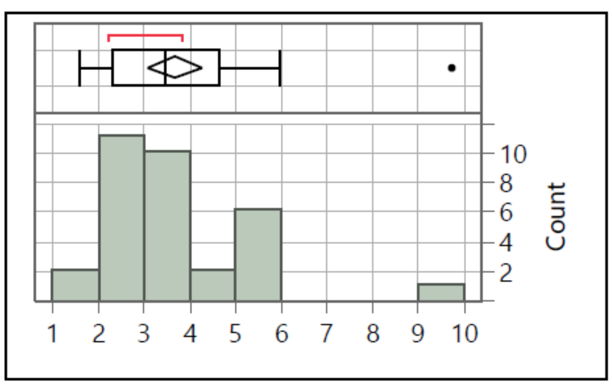
Study participants contributed varying amounts of daily PVT data, making an evaluation of accuracy extremely challenging. The ultimate goal of assessing this aspect of performance was to determine if a participant's accuracy varied between phases, between status groups, or if any particular day within the course showed signs of a collective degradation in accuracy. An error is any response that was < 100ms or ≥ 355ms. Figure 30 shows the initial descriptive analysis of the total number of errors by day throughout the course. This initial assessment shows that students appear to have made more errors on a daily basis than staff members and that there are no major on a daily basis or between phases. To evaluate the accuracy of study participants, two new variables were created: "Daily Error Ratio" and "Phase Error Ratio." The primary output metrics of interest are each participant's number of FS (RT < 100ms) and Lapses (RT ≥ 355ms) for any given trial and these are then normalized by the number of trials taken on a particular day. This process is different from that outlined for calculating response speed. In the calculations for response speed, the number of FS is removed to prevent bias. Here, the number of FSs is a key metric to evaluate accuracy. Appendix J outlines the steps used to conduct this portion of the data cleaning. Figure 31 shows the distribution of each participant's mean error ratio for the entire course. Table 17 shows the PVT error ratio summary statistics for WTI 2-16. Both Figure 30 and Table 17 supports that in general the students appear to have more errors than the staff.

Figure 30. Total Errors by Performance Day.



Performance Days represent the day in which a PVT was taken. PVT trials were consolidated so that any trial occurring from 0500–2359 was assigned to a single Performance Day. Each error bar is constructed using one standard deviation from the mean. The smoother applied uses a cubic spline with lambda 0.05 and x-values are standardized.

Figure 31. Distribution of Participant Mean Error Ratio.



The distribution of mean participant error ratios (s) for WTI 2-16 is based on each of the 32 participants' mean daily error ratio.

Table 17. Error Ratio Summary Statistics.

	Status	Max	Min	Mean +/- SD	Median
Phase	All (n=32)	9.74	1.60	3.67(+/- 1.65)	3.47
Academic	Students (n=11)	7.98	2.64	4.49 (+/- 1.72)	4.79
	Staff (n=21)	6.18	1.64	3.27 (+/- 1.67)	3.39
Flight	Students (n=11)	12.50	1.93	4.67 (+/- 2.88)	3.88
	Staff (n=21)	7.61	1.17	3.13(+/- 1.64)	2.46

Tests for statistical significance were conducted to compare PVT error ratios between the two phases and the two status groups. Wilcoxon rank sum tests were performed to compare the speed of the two status groups. Table 18 is a summary of these results and shows that in both the academic phase and the flight phase, students committed more errors than the staff. In the academic phase, the difference in the error ratio was shown in a p-value of 0.03. This difference decreased slightly in the flight phase but was still statically significant with a p-value of 0.04.

Additionally, within-subjects matched pairs analysis was done to compare the difference in error ratios between the academic phase and the flight phase. These results are summarized in Table 19 and did not reveal any significant change in speed between the two phases.

Table 18. Statistical Test Comparisons of Error Ratios of the Students and Staff.

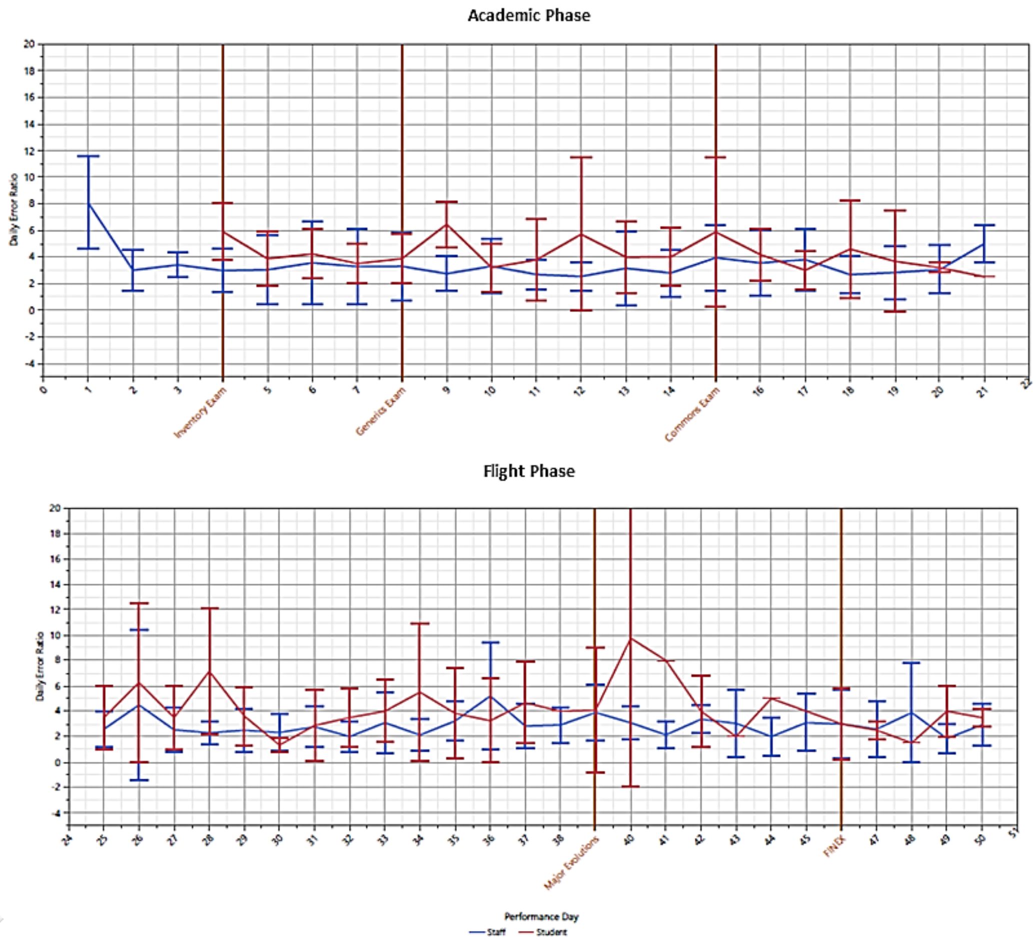
Status Comparison (Wilcoxon)		
	Z	p-value
Academic	2.22	0.03
Flight	2.02	0.04

Table 19. Statistical Test Comparisons of Error Ratios for the Academic and Flight Phases.

Phase Comparison (Within-subjects Matched Pairs)		
	t-ratio	**p-value**
Students (n=11)	0.30	0.77
Staff (n=21)	-0.52	0.61

Lastly, descriptive analysis was conducted to determine if there were any differences in accuracy by day. Figure 32 shows the results of this descriptive analysis. From this analysis, we see an increase in the error ratio that occurred just after the start of Major Evolutions (Day 40) for students. This increase is still within the error margins but is of interest given the portion of training in which it occurs. The participants considered for PVT accuracy analysis are not equivalent to those considered for sleep duration and efficiency. However, an examination of both Figure 20 and Figure 22 for trends in sleep duration and efficiency does not suggest anything unusual for duration or efficiency for the sleep on Night 39.

Figure 32. PVT Error Ratios (s) for Students and Staff by Day.



Performance Days represent the day in which a PVT was taken. PVT trials were consolidated so that any trial occurring from 0500–2359 was associated to a single Performance Day. Each error bar is constructed using one standard deviation from the mean.

This thesis attempted to incorporate a large amount of objective PVT gathered over the course of several weeks from a diverse group of participants. The variability in participation for the contributions of both the PVT and the sleep data presented challenges in drawing definitive conclusions regarding sleep and performance. However, this data collection proved useful in allowing for some limited comparison of the participant performance for speed and accuracy of responses. In general, there were no major differences between the two phases or on a daily basis. However, the staff appear to consistently have faster response times and fewer errors than the students. Additionally, the collection of this data outside of a structured laboratory environment

helped identify several of the challenges in cleaning and processing the information and led to the development of a repeatable process that could be refined or automated as part of future work.

F. QUESTIONNAIRES

Questionnaires were administered three times throughout the WTI 2-16 course for subjective assessment of fatigue. Although several questionnaires were completed, POMS, ISI, PISQ, MEQ, and ESS, analysis for this thesis focused on the scores associated with the two POMS subscales, Total Mood Disturbance (TMD) and POMS Fatigue (F), and Epworth Sleepiness Scale (ESS). Participants who failed to fully complete any of the questionnaires were removed. Consequently, data from only 52 participants was used. All questionnaire data was analyzed using the statistical software package RStudio.

1. POMS

The POMS Total Mood Disturbance (TMD) score is based on a scale from -32 to 200 and is described in more detail in Chapter III. Figure 33 shows the distribution of POMS TMD scores over the three time periods when the questionnaires were administered. Analysis of the TMD scores explored the null hypothesis that there was no change in mood throughout WTI 2-16. To analyze the differences in TMD scores throughout the course, normality was not assumed and a Friedman, rank sum chi-squared test was used to determine if participants' mood changed as a result of time throughout the course (Rice, 1995). Further testing was done using Wilcoxon signed rank test to identify between which pair of questionnaires the most significant changes occurred (Rice, 1995). Table 20 summarizes these comparisons. The Friedman test of all 52 participants across all three questionnaires showed that mood worsened throughout the course (p-value = 0.01) and was most apparent among the staff members (p-value 0.04). Wilcoxon test comparisons for the staff further identify these changes as occurring most between the first administration of questionnaires (T1) and the second administration of questionnaires (T3) with a p-value < 0.001 and more specifically between the second administration (T2) and T2 with a p-value of 0.02.

Figure 33. Distribution of POMS TMD Scores for WTI 2-16.

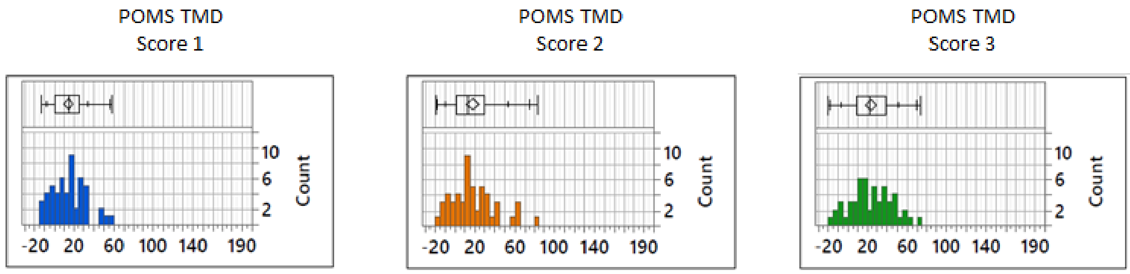


Table 20. POMS TMD Comparison for WTI 2-16.

	TMD Comparisons (p-values)			
	Friedman	Wilcoxon		
		T1 vs. T2	T2 vs T3	T1 vs T3
All (n=52)	0.01	0.37	0.02	<.001
Students (n=17)	0.12	0.24	0.43	0.08
Staff (n=35)	0.04	0.87	0.02	0.02

Friedman tests were conducted to determine the overall change in mood throughout the WTI 2-16 course. Wilcoxon rank sum tests were conducted to identify during which period of time changes in mood occurred. T1 represents the first administration of the questionnaire, T2 represents the second administration of questionnaires, and T3 represents the third administration of questionnaires throughout the course.

The POMS Fatigue (F) subscale is scored on a scale from 0 to 28 and is described in more detail in Chapter III. Figure 34 shows the distribution of POMS F scores over the three time periods when the questionnaires were administered. Analysis of the POMS F scores tested the null hypothesis that there was no change in fatigue throughout WTI 2-16. Results from Friedman tests on all participants as well as on the separate status groups rejected the null hypothesis and found there was an increase in fatigue throughout the course (p-value < 0.001). Specifically, in the staff, this increase was statistically significant with a p-value < 0.001. Further analysis using Wilcoxon signed rank tests revealed that these changes were most noticeable between T2 and T3 as well as between T1 and T3 (p-values < 0.001). Although the increase in fatigue was not as significant, there was still an increase among students as well. With p-values of 0.01 between T1 and T3 and also between T2 and T3. Table 21 summarizes these results. Figure 35 illustrates the change in fatigue using box plots of the reported POMS F scores and shows, in green,

a large increase in both median and variability of T3 compared to the other two time periods.

Figure 34. Distribution of POMS F Scores for WTI 2-16.

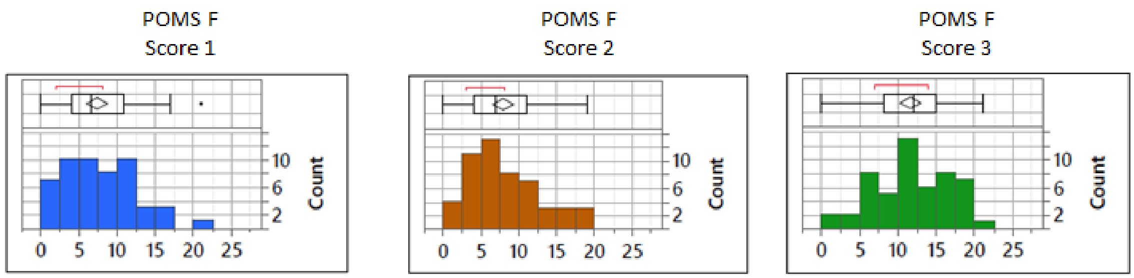
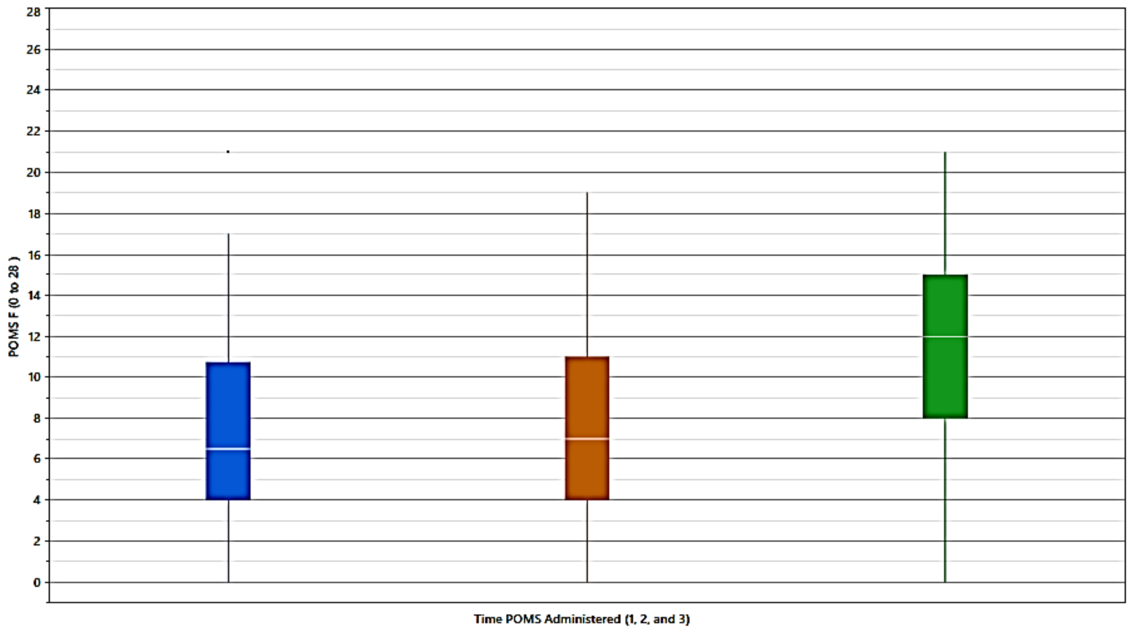


Table 21. POMS F Comparison for WTI 2-16.

	POMS F Comparisons (p-values)			
	Friedman	Wilcoxon		
		T1 vs. T2	T2 vs T3	T1 vs T3
All (n=52)	<.001	0.68	<.001	<.001
Students (n=17)	0.03	0.48	0.01	0.01
Staff (n=35)	<.001	0.77	<.001	<.001

Friedman tests were conducted to determine the overall change in fatigue throughout the WTI 2-16 course. Wilcoxon rank sum tests were conducted to identify during which period of time changes in mood occurred. T1 represents the first administration of the questionnaire, T2 represents the second administration of questionnaires, and T3 represents the third administration of questionnaires throughout the course.

Figure 35. Box Plot of POMS F Scores for WTI 2-16.



2. ESS

ESS is scored on a scale from 0 to 24 and is described in more detail in Chapter III. In particular, the change in ESS scores focused on the number of participants who reported scores > 10 and the increase in this number between the three administrations of the questionnaires. Several references cite an ESS score of 10 as the highest value considered for a normal amount of daytime sleepiness in clinical trials (Johns 1991; Johns, 1994; Johns 1998). Figure 36 shows the distribution of ESS scores over the three time periods when the questionnaires were administered. Analysis of the ESS scores tested the null hypothesis that there was no change daytime sleepiness throughout WTI 2-16. Distribution of ESS Scores for WTI 2-16 uses the McNemar tests for marginal homogeneity. McNemar's test was selected in order to do a matched pairs analysis with the data categorized as either above or below a score of 10, and with sequential tests that were not independent (Rice, 1995). Table 22 summarizes these results and shows that over time there was an increase in the number of participants reporting daytime sleepiness. For all participants combined, this increase was seen between T1 and T2 (p-

value = 0.01) and T1 vs. T3 (p-value = 0.01). Specifically, this trend is seen between T1 vs. T3 for the staff participants (p-value = 0.03).

Figure 36. Distribution of ESS Scores for WTI 2-16.

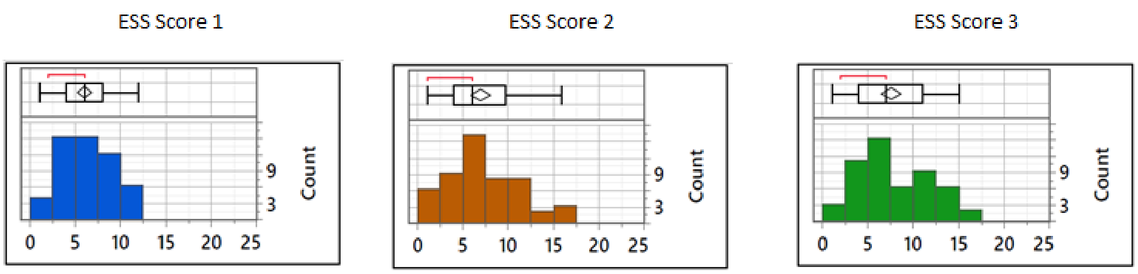


Table 22. ESS Comparison for WTI 2-16.

McNemar Comparisons (p-values)			
	T1 vs. T2	T2 vs. T3	T1 vs. T3
All (n=52)	**0.01**	0.75	**0.01**
Students (n=17)	0.25	1.00	0.48
Staff (n=35)	0.07	0.45	**0.03**

Collectively, both sets of questionnaires, the POMS and the ESS, provide indications that there was an increase in self-reported fatigue over the course of WTI 2-26. Further detailed analysis of the questionnaires was outside the scope of this thesis, but is an excellent opportunity for follow-on research and analysis.

G. RESULTS

Results support the idea that students were well-rested and were using crew rest periods appropriately. Analysis of the sleep data showed that participants in the course generally received between 7 and 8 hours of highly efficient sleep per night. Using objective sleep actigraphy, there were no indications of chronic sleep deprivation in either phase of the course or between students or staff. Exam scores were not a good assessment of performance throughout the course because everyone who provided test scores performed well and had high quality sleep. The objective measures of PVT speed

and accuracy supported the finding that there were no major changes in performance throughout the course. Additional PVT analysis of 1/RT and participant error ratios present findings that in general, the staff performed more quickly and with fewer errors than the student participants. Although it was difficult to analyze the various amounts and quality of PVT data, it did provide an opportunity to document a repeatable process that can be built upon in the future. Subjective assessments via questionnaires suggested an increase in fatigue over the course but this finding cannot be confirmed with objective data.

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V. DISCUSSION

A. SUMMARY

Before sharing the conclusions from this study, a few items should be mentioned to put the discussion into context. The original Maynard (2008) WTI sleep and performance study was requested as a result of mishaps/several near misses that had occurred during prior training courses. For the current study, we set out to see whether mishap rates, attrition rates, or exam scores were related to sleep patterns. It is important to note that over that the seven-week WTI 2-16 course, there were no major mishaps or injuries. Course attrition, one of the major metrics of the study, could not be evaluated because all study participants completed the course. Furthermore, all participants performed very well on academic exams; consequently, this metric also proved to be unhelpful. The facts that there were no mishaps in the course, that all study participants completed the course, and that exam scores were very high should all be seen as good outcomes. These facts support the belief that the MAWTS-1 leadership is setting staff and students up for success and performing well in several areas of TRM.

The focus of this thesis was to determine, outside of a structured laboratory environment, if the performance of an individual participating in WTI 2-16 course was impacted by either the quantity or quality of sleep they received. This question was addressed using various objective and subjective measures of performance and fatigue. Sleep quantity and quality were evaluated using actigraphy data from 11 staff members and six students. Subjective data included three sets of questionnaires collected throughout the course. Specifically, differences in the time across the self-reported POMS TMD, POMS F, and ESS scores from 52 participants were statistically significant.

In general, results from the objective sleep data showed that throughout the course, there was good sleep quantity and quality. Based on the individual mean sleep durations of 17 participants with actigraphic recordings for the entire course, mean participant sleep duration for WTI 2-16 was 7.40 hours (7 hours and 24 minutes) with a standard deviation of 0.48 hours (29 minutes). Mean participant sleep efficiency for the

course was 95.06% with a standard deviation of 2.52%. Furthermore, nights in the course that appeared to have a lower average amount of sleep were followed by nights with greater than average sleep. This finding confirmed that students and instructors were using crew rest periods effectively.

An additional research question considered if there was any portion of the curriculum where either students or the staff were sleep deprived. Based on the objective actigraphic data collected, insufficient sleep did not appear to be an issue. However, results from the questionnaires, specifically an increase in the POMS Fatigue subscore and an increase the number of participants reporting ESS scores >10, indicate that self-reported fatigue increased over the course. In particular, the POMS F scores for all participants worsened over the course of the study. The changes for the student group were reflected in p-values = 0.01 between the second and third administration and the first and third administration. For the staff, the changes in POMS F scores were more severe and were reflected in p-values <.001 between the second and third administration and the first and third administration.

Objective performance data, collected in the form of psychomotor vigilance tests (PVT) scores, showed consistent performance throughout the course with respect to speed and accuracy for PVTs. However, the staff appeared to have consistently faster response times and fewer errors than the students. With the objective data showing overall good sleep habits for study participants and consistent PVT performance, there was no evidence to suggest that poor sleep patterns have a negative effect on performance. Additionally, the collection of this data outside of a structured laboratory environment helped identify several of the challenges in cleaning and processing the information and led to the development of a repeatable process that could be refined or automated as part of future work.

This thesis also compared these results to the WTI 2-05 course results. For WTI 2-05 (n = 20), nightly sleep averaged 7.05 hours (7 hours and 3 minutes) with a standard deviation of 0.48 (29 minutes) but did not report sleep efficiency (Maynard, 2008). As previously mentioned, the 17 WTI 2-16 GS participants' mean sleep duration was 7.40 (7 hours and 24 minutes) with a standard deviation of 0.48 (29 minutes) with typically high

sleep efficiency. This comparison suggests that average sleep duration has remained relatively consistent for the WTI staff and students over the past 10 years.

One consideration for this study was the participants themselves. There is a possibility, that the students and staff who elected to participate in the study were those who achieved the greatest amount of sleep. Furthermore, there is no way of determining if those who did not participate received sufficient sleep in either quantity or quality. Additionally, the thesis can only summarize the results of the data received, meaning that if a participant removed their actiwatches on a night when they did not receive sufficient sleep, we would have no way of knowing. Finally, due to the significant drop in participation at the halfway point of the study, it is possible that participants who knew they would start sleeping less may have elected to drop out. Regardless of these concerns, there are several areas of additional research that can be explored with both the existing data collected from the WTI 2-16 course as well as strong recommendations to improve future studies of this nature.

B. FUTURE WORK

The information gathered and the processes initiated through this thesis present incredible opportunities for future work. Future and follow-on work of interest includes continuation and use of the data gathered in this study as well as improvements to the future studies.

1. Current Study Continuation

Several areas of analysis were beyond the scope of this thesis. Opportunities still exist to analyze the FAST predicted effectiveness levels and compare these to actual PVT performance. There are several other PVT and actigraphic output metrics that could be analyzed to potentially provide further insights. Additionally, there are opportunities to address concerns that other factors (such as room assignments, environmental controls, and light exposures) could be affecting sleep quality. These concerns could potentially be addressed with the PSIQ, ISI, and MEQ questionnaire responses. Follow-on work could also consider the circadian effects of comparing those PVTs taken in the morning versus those taken in the evening.

2. Considerations for Future Studies

There are three categories of recommendations for future studies based on lessons learned. The three categories are participation and data collection; data processing; and measuring performance.

a. Participation and Data Collection

For a study of this nature to achieve and maintain maximum participation, the duration should be carefully considered. Collecting actigraphy over a long period of time can be useful and potentially provide valid insight, but wearing the actiwatch all day everyday can be cumbersome to some participants. Particularly for aviators, the actiwatch was not helpful because it could not be synchronized prior to flight operations. In addition to improving the actual actiwatches, splitting data collection up into smaller segments (such as two week increments) might improve study compliance. Future studies that plan to evaluate sleep and performance over extended periods of time should download actigraphy and PVT data early and often. This process will detect any issues with data collection software, provide early feedback on results, and possibly incentivize continued involvement.

b. Data Processing

One of the greatest limitations and challenges of this study was the tedious and manual nature of data consolidation and cleaning. In particular, visual inspection and scoring of actigraphic data, as well as its comparison to activity logs, consumed several hours of research time. On average, a thorough evaluation of a single participant's sleep file took approximately 20 minutes. With 131 individual sleep files, this evaluation comes out to roughly 44 hours spent just scoring sleep data. Future work could specifically focus on machine learning software development that can assist in more efficiently and scientifically evaluating raw sleep data in larger populations and devices that eliminate the need for verification via activity log.

Using several different metrics such as actigraphy, PVT, and questionnaires presents challenges in the data consolidation and cleaning stages. Additionally, the initial

selection to analyze PVT data utilizing the JMP software made minor adjustments and corrections very difficult. Future studies of this nature should invest time up front to determine focused metrics as well as systematic analysis steps for evaluation of PVT data, working to develop computer code that will easily read in, consolidate, and clean this kind of data. Computer programs such R, RStudio, or Python might offer advantages for this kind of consolidation and cleaning that are not as easily found with JMP and Excel. Researchers should assign phase days and nights at the beginning of the study and ensure that "performance days" correspond to "sleep nights." This action was taken midway through this research and earlier implementation might have accelerated analysis.

With a large study population and the requirement for repeated subjective testing using questionnaires, automating questionnaire responses is highly encouraged. There are three reasons questionnaires should be administered electronically: 1) it will prevent ambiguity in responses because the participant can only select a single answer (in contrast, study participants for this thesis often provided answers such as "1 or 2" or "3 and 4." These were difficult to score and ultimately excluded from this analysis; 2) electronic administration of the questionnaire avoids the necessity to manually enter responses for scoring, thus reducing error; and 3) an electronic exam could provide an option for the participant to look up a definition if they are confused by a vocabulary word (which occurred on a few of the POMS questionnaires).

c. Measuring Performance

In both the current study as well as in the Maynard (2008) study, there was a desire to evaluate the sleep patterns and performance of key billet holders. Unfortunately, there is still no conclusive way for researchers to evaluate this concept. If this is a concern for future studies, a thorough development of standardized evaluation criteria must be developed between course leadership and researchers. A more homogenous group of participants along with implementing procedures to encourage objective compliance might allow for more correlations to be drawn between the objective and subjective reports.

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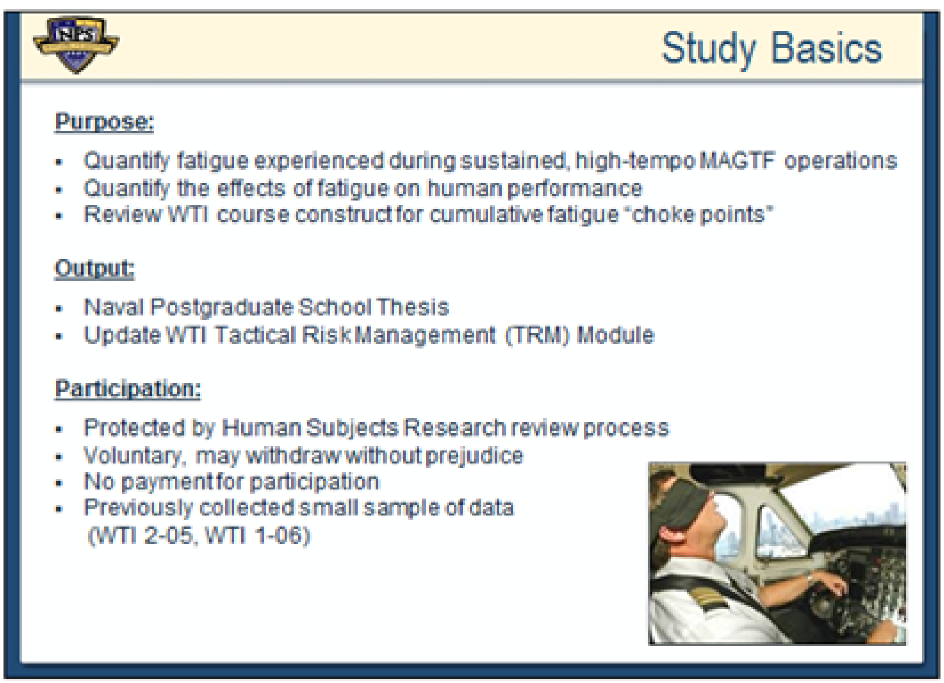
APPENDIX A. RECRUITMENT BRIEF

This presentation was created by Major Matthew Bohman and was provided to the participants of the WTI 2-16 course (personal communication, March 6, 2016).



Fatigue Questionnaires

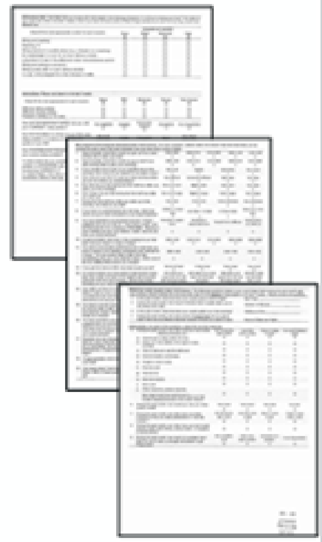
Epworth Sleepiness Scale (ESS): Provides a measure of a person's general level of daytime sleepiness, or their average sleep propensity in daily life. It has become the world standard method for making this assessment.

Pittsburgh Sleep Quality Index (PSQI): Standardized sleep questionnaire containing 19 questions. A global PSQI score is taken from the survey, with lower scores correlating to better sleep quality.

Morningness-Eveningness Questionnaire (MEQ): Measures whether a person's circadian rhythm produces peak alertness in the morning, in the evening, or in between.

Profile of Mood State (POMS): Psychological rating scale used to assess transient, distinct mood states. The long form of the POMS consists of 65 adjectives that are rated by subjects on a 5-point scale.

Insomnia Severity Index (ISI): Assess the severity of both nighttime and daytime components of insomnia. It is available in several languages and is increasingly used as a metric of treatment response in clinical research.



Sleep watches

- Wrist watch-like device worn continuously except when showering

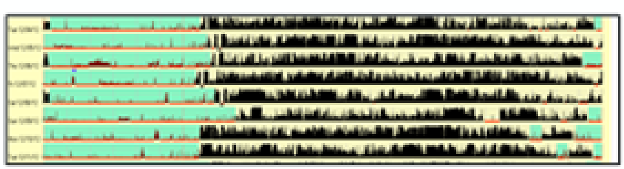
AMI PVT

- x140 Devices
- Built-in PVT
- Off-wrist detection

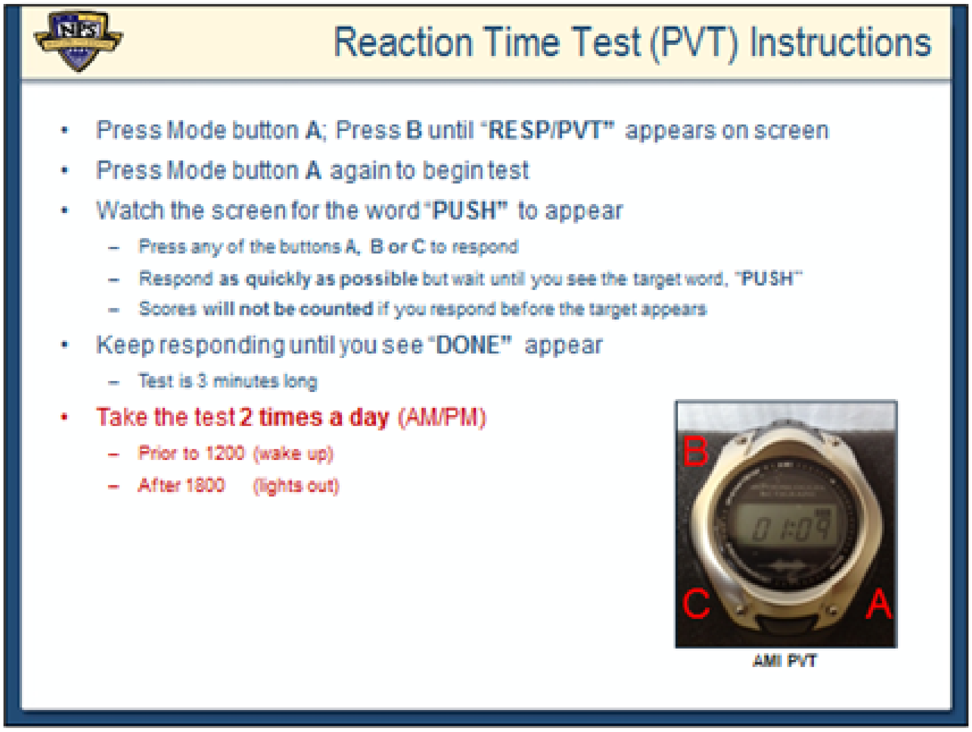
Respironics

- x100 Devices
- No PVT
- Off-wrist detection

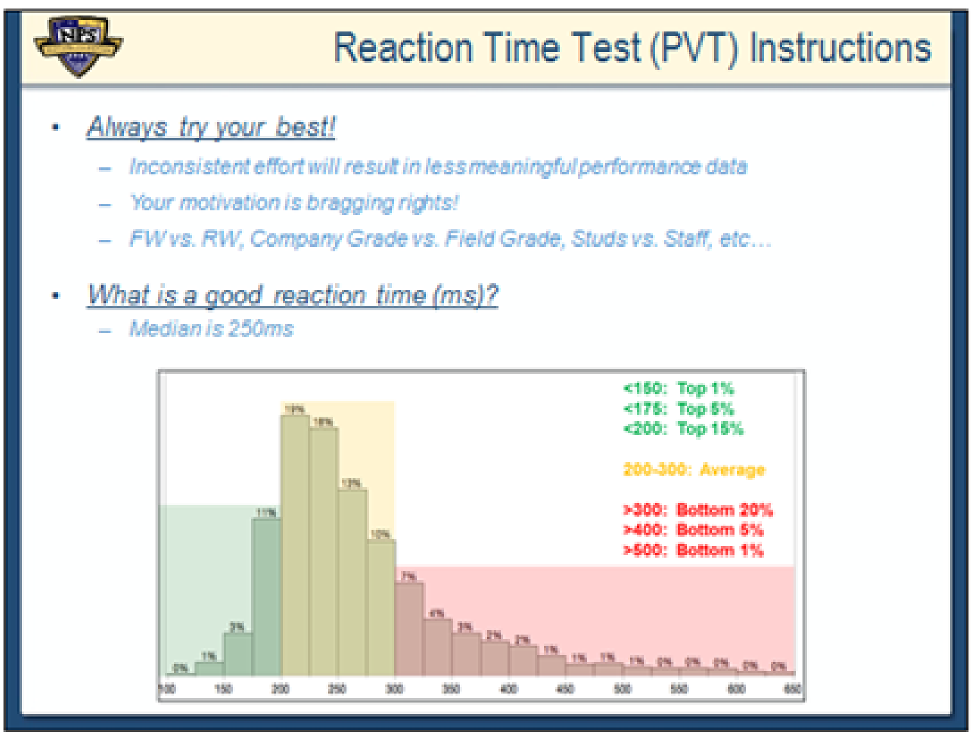
- Measures movement to determine sleep quantity & quality
- Built-in PVT Reaction test to determine cognitive performance (AMI watches)



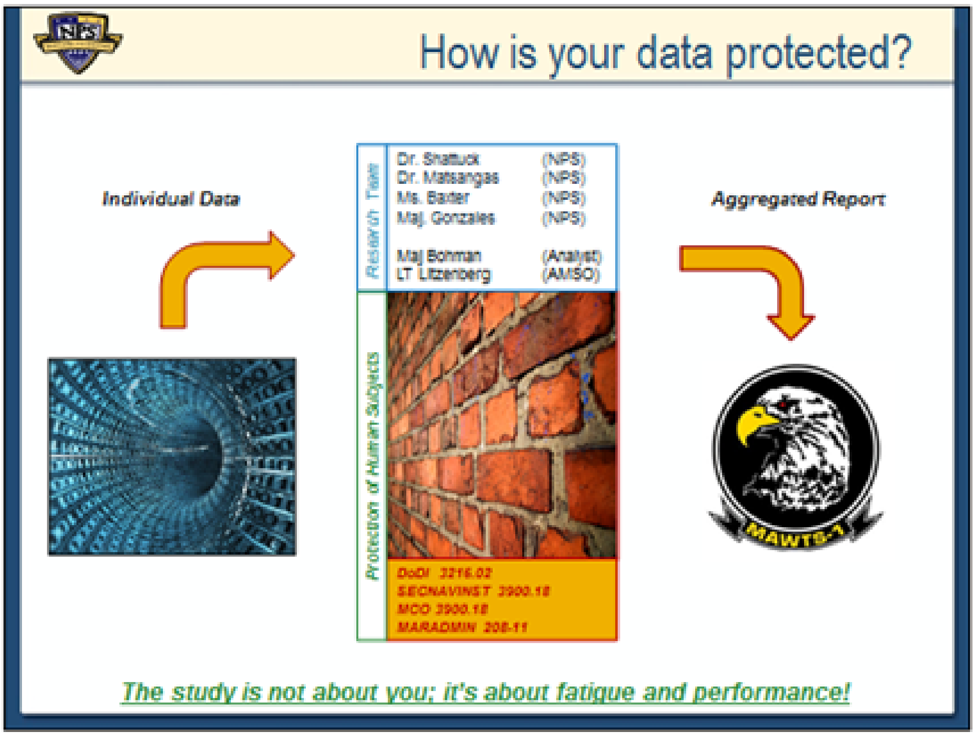
Example of sleep watch activity data output



Reaction Time Test (PVT) Instructions
• Press Mode button A; Press B until "RESP/PVT" appears on screen
• Press Mode button A again to begin test
• Watch the screen for the word "PUSH" to appear
– Press any of the buttons A, B or C to respond
– Respond as quickly as possible but wait until you see the target word, "PUSH"
– Scores will not be counted if you respond before the target appears
• Keep responding until you see "DONE" appear
– Test is 3 minutes long
• Take the test 2 times a day (AM/PM)
– Prior to 1200 (wake up)
– After 1800 (lights out)
B
C
A
AMI PVT



Reaction Time Test (PVT) Instructions
• Always try your best!
– Inconsistent effort will result in less meaningful performance data
– Your motivation is bragging rights!
– FW vs. RW, Company Grade vs. Field Grade, Studs vs. Staff, etc…
• What is a good reaction time (ms)?
– Median is 250ms
<150: Top 1%
<175: Top 5%
<200: Top 15%
200-300: Average
>300: Bottom 20%
>400: Bottom 5%
>500: Bottom 1%
100 150 200 250 300 350 400 450 500 550 600 650



NPS Fatigue Study Team

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LT Litzenberg (MAWTS-1 AMSO)
Maj Gonzales (USMC, NPS thesis student)
Dr. Matsangas (NPS Post-doctoral Associate)
Ms. Baxter (NPS Research Assistant)

Questions?

Q: What data does the device collect?
A: Motion, on/off person, PVT. There is no GPS, heartrate, step count, etc...

Q: Is it ok in secure spaces?
A: Yes. It is a stand-alone device with no connectivity capability.

Q: What if I'm up way past my bedtime and flying the next day? Can I get in trouble?
A: No. Individual data is only handled by legally bound research team. Published data will be displayed in aggregate. Altering behavior or removing device would corrupt the study and result inaccurate findings. Please provide an accurate PWTI/IP "pattern of life".

Q: What if my device breaks, runs out of battery, or otherwise fails?
A: Contact Maj Bohman directly (928-269-3265) or give defective device to Div/Dept IP. Continue filling out activity log.

Q: What if I forget to wear the watch for a few days or forget to take the PVT?
A: Please continue with the study as soon as you remember. Valuable data can be collected even if there are gaps.

Q: Will the results of the study be available to me?
A: Yes. You can contact the research team directly for updates as desired. An NPS thesis in Operations Research will be published and available open-source in spring/summer 2017.

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APPENDIX B. CONSENT FORM EXAMPLE

Naval Postgraduate School
Consent to Participate in Research

Introduction. You are invited to participate in a research study entitled ***"Marine Aviation Weapons and Tactics Squadron one (MAWTS-1) ten year retrospective study of sleep, fatigue, and performance".*** The purpose of this project is to investigate the current work and rest schedule of instructors and students at MAWTS-1 and to assess the effect of sleep and fatigue on performance at various times throughout the WTI 2-16 course.

Procedures. If you agree to participate in this study, the researchers will explain the study tasks in detail. During your participation in this study, you will initially be asked to answer a survey with questions about your demographic information, sleep patterns, sleep quality, fatigue, and mood (approx. 20 minutes total). You will have to complete a survey at the mid-point of the WTI course, and at the end of the data collection period (20 minutes to complete). Throughout the study period, you will be asked to wear a sleep watch to measure the amount and quality of sleep you receive. Sleep watches will be worn 24 hours a day for the duration of the study; you should remove the sleep watch when showering or swimming. You will be administered an activity log to report your activity and your sleep times (approximately 5 minutes total per day to complete). Additionally, you may be asked to perform the 3-minute Psychomotor Vigilance Task (PVTs) two times per day, once in the morning, and once before you go to bed. No Personally Identifiable Information (PII) will be stored with the data. The study will last 7 weeks. By participating in this study you agree to release your exam scores and evaluations to the research team. These will be used for research purposes only.

Location. The study will take place at the MAWTS-1 training facility in Yuma, AZ and all training areas associated with the WTI 2-16 course.

Cost. There is no cost to participate in this research study.

Voluntary Nature of the Study. Your participation in this study is strictly voluntary. If you choose to participate, you can change your mind at any time and withdraw from the study. You will not be penalized in any way or lose any benefits to which you would otherwise be entitled if you choose not to participate in this study or to withdraw. The alternative to participating in the research is to not participate in the research.

Potential Risks and Discomforts. The potential risks of participating in this study are minimal. There is a minor risk of breach of privacy and confidentiality. All personal identifiable information will be concealed once the data from the study has been collected. All data will be presented based on group analysis; individuals will not be singled out or identifiable, unless you provide consent below to be identified or quoted. Raw data will not be disclosed to anyone outside the research team.

Anticipated Benefits. There will be no direct benefit for the individual participants; however, this study may ultimately benefit the military and specifically MAWTS-1 to improve the course structure and curriculum. At the end of study, subjects will have the opportunity to review and discuss their sleep data with the PI.

NPS IRB
APPROVED
FEB 26 2016
EXPIRES
FEB 17 2017

Compensation for Participation. No tangible compensation will be given.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. All data from this study will be kept on a secure server and/or in a locked facility and only the researchers will have access to the data.

If you consent to be identified by name in this study, any reference to or quote by you will be published in the final research finding only after your review and approval. If you do not agree, then you will be identified broadly by discipline and/or rank, (for example, "pilot").

☐ I consent to be identified by name in this research study. My email address is - ________________ for final approval of any associated reference or quote in future publications regarding this research.

☐ I do not consent to be identified by name in this research study.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, Dr. Nita Lewis Shattuck, 831-656-2281, nlshattu@nps.edu or the on-site point of contact, Maj Matt Bohman, 928-269-3265, matthew.bohman@usmc.mil. Questions about your rights as a research subject or any other concerns may be addressed to the Naval Postgraduate School Institutional Review Board, Dr. Ken Euske, kjeuske@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

________________________________ ________________

Participant's Signature Date

________________________________ ________________

Researcher's Signature Date

NPS IRB
APPROVED
FEB 26 2016
EXPIRES

APPENDIX C. QUESTIONNAIRE EXAMPLES

MAWTS-1 study of sleep, fatigue, and performance

Date: ____________ Participant ID: ____________

Pre-Study Questionnaire

Instructions: *Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.*

1. What is your branch of service? (Check one ☑)
   ☐ Army ☐ Navy ☐ Air Force ☐ Marine Corps ☐ DoD Civilian ☐ Contractor
2. Please indicate your current role at MAWTS-1 by checking the block next to the correct response:
   ☐ Instructor ☐ Student ☐ Other If other, please state your role ____________
3. What is your age: ____________ years
4. What is your gender (Check one ☑) ☐ Male ☐ Female
5. What is your job specialty/job title (rate, MOS, AOC, AFSC)?
   (for example, 7555, 0402, etc.) ____________
6. What is your rank: (for example, E4, O2, etc.) ____________
7. How long have you been in the military? (example: 2 yrs 3 months): ____________
8. Do you live with members of your family (for the duration of WTI2-16)? ☐ Yes ☐ No
   If YES, please check all the members of you family who live with you now.
   ☐ Spouse
   ☐ 1st child Age: _____ years
   ☐ 2nd child Age: _____ years
   ☐ 3rd child Age: _____ years
   ☐ 4th child Age: _____ years
   ☐ Other people living in the same house
9. Do you use tobacco or tobacco products? (Check one ☑) ☐ Yes ☐ No
   If YES, which of the following nicotine products do you use? (Check ALL that apply ☑) and indicate how often)
   ☐ Cigarettes (If YES, how often? ____________)
   ☐ Chewing tobacco/snuff (If YES, how often? ____________)
   ☐ Nicorette gum or patches (If YES, how often? ____________)
   ☐ Electronic smoke (If YES, how often? ____________)
   ☐ Other (specify): ____________ (How often? ____________)
10. Do you take any prescribed or over-the-counter medications? (Check one ☑) ☐ Yes ☐ No
    If **YES**, please list all medications you take: ____________
    ____
11. Have you ever been diagnosed with a sleep-related disorder? (Check one ☑) ☐ Yes ☐ No
12. Do you have an exercise routine? (Check one ☑) ☐ Yes ☐ No
    If **YES**, frequency: ____Daily ____Times per week (for example, 3 Times per week)
    What kind of exercise routine do you do? (for example, cardio, weight lifting)
    ____
    How long does this routine take? (for example, 45 minutes) ____________

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Instructions: *If you are an Instructor in MATWS-1 please answer the following questions. Otherwise go the next set of questions.*

13. How long have you been at MAWTS-1? ______Years ______Months
14. What is your department? (example: S-3, Safety, etc.) ____________
15. What was your position before arriving at MAWTS-1? ____________
16. On your current schedule, what days do you come in to work and how many hours, on average, do you spend working each day? (example: 9 Mon 10 Tues 9 Wed 8 Thu 9 Fri 3 Sat 0 Sun)

    ___ Mon ___ Tue ___ Wed ___ Thu ___ Fri ___Sat ___ Sun
17. In a typical workweek when a class is not in session, what hours do you usually work? (example: Start: 0730 End: 1630) Start: ______ End: ______
18. In a typical workweek when class is convened, what hours do you usually work? (example: Start: 0730 End: 1630) Start: ______ End: ______
19. On average, how many breaks (authorized or unauthorized) do you take under the current schedule? (A break is any period of time in which you are able to sit down and eat at the same time.) **[Note: Survey anonymity is promised so please answer honestly.]**
    (example: 4 breaks of 15 minutes and 2 breaks of 30 minutes)

    ____

Instructions: *If you are a Student in the WTI please answer the following questions. Otherwise go the next set of questions.*

20. What is your division? (example: fixed wing, rotary, AGS, etc.) ____________
21. If you are a pilot, how many hours of flight experience do you have? ____________
22. If you are a pilot, what types of aircraft have you flown? ____________
23. When did you start your travel to come to MAWTS-1 in Yuma? (example: March 3) ____________
24. Location from which your travel to MAWTS-1 began (state or country): ____________
25. How many days have you been in Yuma, AZ? ____________

Epworth Sleepiness Scale (ESS)

Instructions (All) : *How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in the last 3 weeks. Even if you have not done some of these things recently try to work out how they would have affected you.*

Check ☑ the most appropriate number for each situation.	CHANCE OF DOZING None (0)	Slight (1)	Moderate (2)	High (3)
Sitting and reading	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Sitting inactive in a public place (e.g. a theater or a meeting)	☐	☐	☐	☐
As a passenger in a car for an hour without a break	☐	☐	☐	☐
Lying down to rest in the afternoon when circumstances permit	☐	☐	☐	☐
Sitting and talking to someone	☐	☐	☐	☐
Sitting quietly after a lunch without alcohol	☐	☐	☐	☐
In a car, while stopped for a few minutes in traffic	☐	☐	☐	☐

The Insomnia Severity Index (ISI)

Instructions: *Please rate based on the last 3 weeks.*

Check ☑ the most appropriate for each situation.	None (0)	Mild (1)	Moderate (2)	Severe (3)	Very Severe (4)
Difficulty falling asleep	☐	☐	☐	☐	☐
Difficulty staying asleep	☐	☐	☐	☐	☐
Problems waking up too early	☐	☐	☐	☐	☐
How SATISFIED/DISSATISFIED are you with your CURRENT sleep pattern?	Very Satisfied ☐	Satisfied ☐	Moderately Satisfied ☐	Dissatisfied ☐	Very Dissatisfied ☐
How NOTICEABLE to others do you think your sleep problem is in terms of impairing the quality of your life?	Not at all Noticeable ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Noticeable ☐
How WORRIED/DISTRESSED are you about your current sleep problem?	Not at all Worried ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Worried ☐
To what extent do you consider your sleep problem to INTERFERE with your daily functioning CURRENTLY? (i.e. daytime fatigue, mood, ability to function at work, concentration, memory, mood, etc.)	Not at all Interfering ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Interfering ☐

Dr. Murray W. Johns (1998) developed the Epworth Sleepiness Scale (ESS) in the early 1990s as an inexpensive, self-administered survey that uses eight different scenarios to score an individual's level of daytime sleepiness.

The Insomnia Severity Index (ISI) assesses an individual's level of insomnia (Morin, Belleville, Bélanger, & Ivers ,2011).

Pittsburgh Sleep Quality Index (PSQI)

Pittsburgh Sleep Quality Index Instructions: *The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days/nights in the last 3 weeks. Please answer all questions.*

1.	In the past month, what time have you usually gone to bed at night?	Bed Time: ______________
2.	During the past month, how long (in minutes) has it usually taken you to fall asleep each night	Number of Minutes: ______________
3.	In the past month, what time have you usually gotten up in the morning?	Getting up time: ______________
4.	During the past month, how many hours of actual sleep did you get at night? (this may be different than the number of hours you spent in bed.)	Hours of Sleep per Night: ______________

Instructions: *For each of the questions, check the one best response.*

5.	During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	3 or more times a week
	a) Cannot get to sleep within 30 mins	O	O	O	O
	b) Wake up in the middle of the night or early morning	O	O	O	O
	c) Have to get up to use the bathroom	O	O	O	O
	d) Cannot breathe comfortably	O	O	O	O
	e) Cough or snore loudly	O	O	O	O
	f) Feel too cold	O	O	O	O
	g) Feel too hot	O	O	O	O
	h) Had bad dreams	O	O	O	O
	i) Have pain	O	O	O	O
	j) Other reason(s), please describe: ______________ How often during the past month have you had trouble sleeping because of this other reason?	O	O	O	O
6.	During the past month, how would you rate your sleep quality overall?	Very Good O	Fairly Good O	Fairly Bad O	Very Bad O
7.	During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?	Not during the past month O	Less than once a week O	Once or twice a week O	Three or more times a week O
8.	During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	O	O	O	O
9.	During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	Not a problem at all O	Only a very slight problem O	Somewhat of a problem O	A very big problem O

The Pittsburg Sleep Quality Index (PSQI) was introduced in the late 1980s and is a validated, 19-question survey used to evaluate the sleep quality of an individual (Backhaus, Junghanns, Broocks, Riemann, & Hogan, 2002).

Morningness Eveningness Questionnaire (MEQ)

Morningness-Eveningness Questionnaire Instructions: *For each question, please select the answer that best describes you by circling the point value that best indicates how you have felt in recent weeks.*

	Question					
1.	Approximately what time would you get up if you were entirely free to plan your day?	0500-0630 ○	0630-0745 ○	0745-0945 ○	0945-1100 ○	1100-1200 ○
2.	Approximately what time would you go to bed if you were entirely free to plan your evening?	2000-2100 ○	2100-2215 ○	2215-0030 ○	0030-0145 ○	0145-0300 ○
3.	If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?	Not at all ○	Slightly ○		Somewhat ○	Very much ○
4.	How easy do you find it to get up in the morning (when you are not woken up unexpectedly)?	Very difficult ○	Somewhat difficult ○		Fairly easy ○	Very easy ○
5.	How alert do you feel during the first half-hour after you wake up in the morning?	Not at all alert ○	Slightly alert ○		Fairly alert ○	Very alert ○
6.	How hungry do you feel during the first half-hour after you wake up?	Not at all hungry ○	Slightly hungry ○		Fairly hungry ○	Very hungry ○
7.	During the first half-hour after you wake up in the morning, how tired do you feel?	Very tired ○	Fairly tired ○		Fairly refreshed ○	Very refreshed ○
8.	If you have no commitments the next day, what time would you go to bed compared to your usual bedtime?	Seldom or never later ○	Less than 1 hr later ○		1-2 hours later ○	More than 2 hrs later ○
9.	You have decided to do physical exercise. A friend suggests that you do this for 1 hour twice a week, and the best time for him is between 0700-0800. Bearing in mind nothing but your own internal "clock", how do you think you would perform?	Would be in good form ○	Would be in reasonable form ○		Would find it difficult ○	Would find it very difficult ○
10.	At approximately what time in the evening do you feel tired, and as a result, in need of sleep?	2000-2100 ○	2100-2215 ○	2215-0045 ○	0045-0200 ○	0200-0300 ○
11.	You want to be at peak performance for a test that you know is going to be mentally exhausting and will last for 2 hours. You are entirely free to plan your day. Considering only your own internal "clock", which one of the four testing times would you choose?	0800-1000 ○	1100-1300 ○		1500-1700 ○	1700-1900 ○
12.	If you got into bed at 2300, how tired would you be?	Not at all tired ○	A little tired ○		Fairly tired ○	Very tired ○
13.	For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?	Will wake up at usual time, but will NOT fall back asleep ○	Will wake up at usual time and will doze thereafter ○		Will wake up at usual time, but will fall asleep again ○	Will NOT wake up until later than usual ○
14.	One night you have to remain awake between 0400-0600 in order to carry out a night watch. You have no commitments the next day. Which ONE of the alternatives will suit you best?	Would NOT go to bed until the watch is over ○	Would take a nap before and sleep after ○		Would take a good sleep before and nap after ○	Would sleep only before watch ○
15.	You have to do two hours of hard physical work. You are entirely free to plan your day; considering only your own internal "clock", which ONE of the following times would you choose?	0800-1000 ○	1100-1300 ○		1500-1700 ○	1900-2100 ○
16.	You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for him is between 2200-2300. Bearing in mind only your internal "clock", how well do you think you would perform?	Would be in good form ○	Would be in reasonable form ○		Would find it difficult ○	Would find it very difficult ○
17.	Suppose you can choose you own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At approximately would you choose to begin?	5 hrs starting between 0400 - 0800 ○	5 hrs starting between 0800 - 0900 ○	5 hrs starting between 0900 - 1400 ○	5 hrs starting between 1400 - 1700 ○	5 hrs starting between 1700 - 0400 ○
18.	At approximately what time of day do you usually feel your best?	0500-0800 ○	0800-1000 ○	1000-1700 ○	1700-2200 ○	2200-0500 ○
19.	One hears about "morning types" and "evening types." Which ONE of these types do you consider yourself to be?	Definitely a morning type ○	Rather more a morning type than an evening type ○		Rather more a evening type than an morning type ○	Definitely an evening type ○

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Horne and Ostberg developed the Morningness Eveningness Questionnaire (MEQ) the mid-1970s which contains 19 questions, each ranked on a 4 point scale. (Baehr, Revelle, & Eastman, 2000).

MAWTS-1 study of sleep, fatigue, and performance

Date: ____________ Participant ID: ______________

Second Questionnaire

Instructions: *This questionnaire refers to your experiences during the last 3 weeks. Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.*

1. What things affected your sleep? (Check ALL that apply ☑)
   - ☐ Not enough time to sleep
   - ☐ Noise: ____Other people ____ Noise inside sleeping quarters ____ Noise outside sleeping quarters
   - ☐ Temperature: ____Too cold ____Too hot
   - ☐ Light
   - ☐ Bedding Conditions: ____Bed size ____Mattress ____Pillow ____ Curtain
   - ☐ Odors
   - ☐ Other things that affect your sleep: ______________________________
     (for example: your family lives in Okinawa and late night was the best time to speak with them)
2. Did you use tobacco or tobacco products? (Check one ☑) ☐ Yes ☐ No

   If YES, which of the following nicotine products do you use? (Check ALL that apply ☑) and indicate how often)
   - ☐ Cigarettes (If YES, how often? ____________)
   - ☐ Chewing tobacco/snuff (If YES, how often? ____________)
   - ☐ Nicorette gum or patches (If YES, how often? ____________)
   - ☐ Electronic smoke (If YES, how often? ____________)
   - ☐ Other (specify): ______________ (How often? ____________)
3. How many of the following caffeinated beverages did you drink **on average** each day?
   (Check ALL that apply ☑) and indicate daily amount)
   - ☐ Tea Servings/Cups per day: ____________
   - ☐ Coffee Servings/Cups per day: ______
   - ☐ Soda/pop/soft drinks Servings/Cups per day: ______
   - ☐ Energy drinks Servings/Cups per day: ______
   - ☐ Other (specify): ______________ How often: ______ (Example: 4 times per day)
4. Did you have an exercise routine? (Check one ☑) ☐ Yes ☐ No

   If **YES**, frequency: ____Daily ____Times per week (for example, 3 Times per week)
   What kind of exercise routine did you do? (for example, cardio, weight lifting)

   ____

   How long did this routine take? (for example, 45 minutes) ______________________

Instructions: *How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in the last 3 weeks. Even if you have not done some of these things recently try to work out how they would have affected you.*

Check ☑ the most appropriate number for each situation.	CHANCE OF DOZING			
	None (0)	Slight (1)	Moderate (2)	High (3)
Sitting and reading	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Sitting inactive in a public place (e.g. a theater or a meeting)	☐	☐	☐	☐
As a passenger in a car for an hour without a break	☐	☐	☐	☐
Lying down to rest in the afternoon when circumstances permit	☐	☐	☐	☐
Sitting and talking to someone	☐	☐	☐	☐
Sitting quietly after a lunch without alcohol	☐	☐	☐	☐
In a car, while stopped for a few minutes in traffic	☐	☐	☐	☐

Instructions: *Please rate based on the last 3 weeks.*

Check ☑ the most appropriate for each situation.	None (0)	Mild (1)	Moderate (2)	Severe (3)	Very Severe (4)
Difficulty falling asleep	☐	☐	☐	☐	☐
Difficulty staying asleep	☐	☐	☐	☐	☐
Problems waking up too early	☐	☐	☐	☐	☐
How SATISFIED/DISSATISFIED are you with your CURRENT sleep pattern?	Very Satisfied ☐	Satisfied ☐	Moderately Satisfied ☐	Dissatisfied ☐	Very Dissatisfied ☐
How NOTICEABLE to others do you think your sleep problem is in terms of impairing the quality of your life?	Not at all Noticeable ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Noticeable ☐
How WORRIED/DISTRESSED are you about your current sleep problem?	Not at all Worried ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Worried ☐
To what extent do you consider your sleep problem to INTERFERE with your daily functioning CURRENTLY? (i.e. daytime fatigue, mood, ability to function at work, concentration, memory, mood, etc.)	Not at all Interfering ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Interfering ☐

Pittsburgh Sleep Quality Index Instructions: *The following questions relate to your usual sleep habits during the last three weeks* *__only__*. *Your answers should indicate the most accurate reply for the* *__majority__* *of days/nights in the last 3 weeks. Please answer all questions.*

1.	In the past month, what time have you usually gone to bed at night?	Bed Time: ______
2.	During the past month, how long (in minutes) has it usually taken you to fall asleep each night	Number of Minutes:______
3.	In the past month, what time have you usually gotten up in the morning?	Getting up time:______
4.	During the past month, how many hours of __actual sleep__ did you get at night? (this may be different than the number of hours you spent in bed.)	Hours of Sleep per Night:______

Instructions: *For each of the questions, check the one best response.*

		Not during the past month	Less than once a week	Once or twice a week	3 or more times a week
5.	During the past month, how often have you had trouble sleeping because you…				
a)	Cannot get to sleep within 30 mins	O	O	O	O
b)	Wake up in the middle of the night or early morning	O	O	O	O
c)	Have to get up to use the bathroom	O	O	O	O
d)	Cannot breathe comfortably	O	O	O	O
e)	Cough or snore loudly	O	O	O	O
f)	Feel too cold	O	O	O	O
g)	Feel too hot	O	O	O	O
h)	Had bad dreams	O	O	O	O
i)	Have pain	O	O	O	O
j)	Other reason(s), please describe: ______ How often during the past month have you had trouble sleeping because of this other reason?	O	O	O	O
6.	During the past month, how would you rate your sleep quality overall?	Very Good O	Fairly Good O	Fairly Bad O	Very Bad O
7.	During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter"?	Not during the past month O	Less than once a week O	Once or twice a week O	Three or more times a week O
8.	During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	O	O	O	O
9.	During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	Not a problem at all O	Only a very slight problem O	Somewhat of a problem O	A very big problem O

MAWTS-1 study of sleep, fatigue, and performance

Date: ____________ Participant ID: ____________

Final Post-Study Questionnaire

Instructions: *This questionnaire refers to your experiences during the last month. Please answer ALL questions as accurately as possible. ALL information is confidential and will be used only for research purposes.*

1. What things affected your sleep? (Check ALL that apply ☑)
   - ☐ Not enough time to sleep
   - ☐ Noise: _____Other people ______ Noise inside sleeping quarters _____ Noise outside sleeping quarters
   - ☐ Temperature: _____Too cold ____Too hot
   - ☐ Light
   - ☐ Bedding Conditions: ____Bed size ____Mattress ____Pillow ______ Curtain
   - ☐ Odors
   - ☐ Other things that affect your sleep: ______________________________
     (for example: your family lives in Okinawa and late night was the best time to speak with them)
2. Did you use tobacco or tobacco products? (Check one ☑) ☐ Yes ☐ No

   If YES, which of the following nicotine products do you use? (Check ALL that apply ☑) and indicate how often)
   - ☐ Cigarettes (If YES, how often? ______________)
   - ☐ Chewing tobacco/snuff (If YES, how often? ______________)
   - ☐ Nicorette gum or patches (If YES, how often? ______________)
   - ☐ Electronic smoke (If YES, how often? ______________)
   - ☐ Other (specify): ______________ (How often? ______________)
3. How many of the following caffeinated beverages did you drink <u>on average</u> each day?
   (Check ALL that apply ☑) and indicate daily amount)
   - ☐ Tea Servings/Cups per day: ____________
   - ☐ Coffee Servings/Cups per day: _______
   - ☐ Soda/pop/soft drinks Servings/Cups per day: _______
   - ☐ Energy drinks Servings/Cups per day: _______
   - ☐ Other (specify): ______________ How often: _______ (Example: 4 times per day)
4. Did you have an exercise routine? (Check one ☑) ☐ Yes ☐ No

   If **YES**, frequency: ____Daily ____Times per week (for example, 3 Times per week)
   What kind of exercise routine did you do? (for example, cardio, weight lifting)

   ____

   How long did this routine take? (for example, 45 minutes) ______________________

Instructions: *How likely are you to doze off or fall asleep in the following situations, in contrast to feeling just tired? This refers to your usual way of life in the last month. Even if you have not done some of these things recently try to work out how they would have affected you.*

Check ☑ the most appropriate number for each situation.	CHANCE OF DOZING			
	None (0)	Slight (1)	Moderate (2)	High (3)
Sitting and reading	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Sitting inactive in a public place (e.g. a theater or a meeting)	☐	☐	☐	☐
As a passenger in a car for an hour without a break	☐	☐	☐	☐
Lying down to rest in the afternoon when circumstances permit	☐	☐	☐	☐
Sitting and talking to someone	☐	☐	☐	☐
Sitting quietly after a lunch without alcohol	☐	☐	☐	☐
In a car, while stopped for a few minutes in traffic	☐	☐	☐	☐

Instructions: *Please rate based on the last month.*

Check ☑ the most appropriate for each situation.	None (0)	Mild (1)	Moderate (2)	Severe (3)	Very Severe (4)
Difficulty falling asleep	☐	☐	☐	☐	☐
Difficulty staying asleep	☐	☐	☐	☐	☐
Problems waking up too early	☐	☐	☐	☐	☐
How SATISFIED/DISSATISFIED are you with your CURRENT sleep pattern?	Very Satisfied ☐	Satisfied ☐	Moderately Satisfied ☐	Dissatisfied ☐	Very Dissatisfied ☐
How NOTICEABLE to others do you think your sleep problem is in terms of impairing the quality of your life?	Not at all Noticeable ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Noticeable ☐
How WORRIED/DISTRESSED are you about your current sleep problem?	Not at all Worried ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Worried ☐
To what extent do you consider your sleep problem to INTERFERE with your daily functioning CURRENTLY? (i.e. daytime fatigue, mood, ability to function at work, concentration, memory, mood, etc.)	Not at all Interfering ☐	A Little ☐	Somewhat ☐	Much ☐	Very Much Interfering ☐

Pittsburgh Sleep Quality Index Instructions: *The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days/nights in the last month. Please answer all questions.*

1.	In the past month, what time have you usually gone to bed at night?	Bed Time: ______________
2.	During the past month, how long (in minutes) has it usually taken you to fall asleep each night	Number of Minutes: ______________
3.	In the past month, what time have you usually gotten up in the morning?	Getting up time: ______________
4.	During the past month, how many hours of actual sleep did you get at night? (this may be different than the number of hours you spent in bed.)	Hours of Sleep per Night: ______________

Instructions: *For each of the questions, check the one best response.*

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month	Less than once a week	Once or twice a week	3 or more times a week
a) Cannot get to sleep within 30 mins	O	O	O	O
b) Wake up in the middle of the night or early morning	O	O	O	O
c) Have to get up to use the bathroom	O	O	O	O
d) Cannot breathe comfortably	O	O	O	O
e) Cough or snore loudly	O	O	O	O
f) Feel too cold	O	O	O	O
g) Feel too hot	O	O	O	O
h) Had bad dreams	O	O	O	O
i) Have pain	O	O	O	O
j) Other reason(s), please describe: ______________ How often during the past month have you had trouble sleeping because of this other reason?	O	O	O	O

6. During the past month, how would you rate your sleep quality overall?	Very Good O	Fairly Good O	Fairly Bad O	Very Bad O
7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter"?	Not during the past month O	Less than once a week O	Once or twice a week O	Three or more times a week O
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	O	O	O	O
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	Not a problem at all O	Only a very slight problem O	Somewhat of a problem O	A very big problem O

Please Print Clearly

First letter of your last name

Last 4 digits of your Social Security Number

ndard Form

W P. HEUCHERT, Ph.D., & LEO F. DROPPLEMAN, Ph.D.

Age:__________ **Gender:** Male Female (Circle one)

/____/____
Day Year

t:

To the Administrator:

Place a checkmark ✔ in one box to specify the time period of interest.

ords that describe feelings that people have. Please read each word carefully. Then circle the number that best describes

☐ how you have been feeling during the PAST WEEK, INCLUDING TODAY.
☐ how you feel RIGHT NOW.
☒ other: PAST 2 WEEKS

If no box is marked, please follow the instructions for the first box.

POMS™

		Not at all	A little	Moderately	Quite a bit	Extremely
1.	Friendly	0	1	2	3	4
2.	Tense	0	1	2	3	4
3.	Angry	0	1	2	3	4
4.	Worn out	0	1	2	3	4
5.	Unhappy	0	1	2	3	4
6.	Clear-headed	0	1	2	3	4
7.	Lively	0	1	2	3	4
8.	Confused	0	1	2	3	4
9.	Sorry for things done	0	1	2	3	4
10.	Shaky	0	1	2	3	4
11.	Listless	0	1	2	3	4
12.	Peeved	0	1	2	3	4
13.	Considerate	0	1	2	3	4
14.	Sad	0	1	2	3	4
15.	Active	0	1	2	3	4
16.	On edge	0	1	2	3	4
17.	Grouchy	0	1	2	3	4
18.	Blue	0	1	2	3	4
19.	Energetic	0	1	2	3	4
20.	Panicky	0	1	2	3	4
21.	Hopeless	0	1	2	3	4
22.	Relaxed	0	1	2	3	4
23.	Unworthy	0	1	2	3	4
24.	Spiteful	0	1	2	3	4
25.	Sympathetic	0	1	2	3	4
26.	Uneasy	0	1	2	3	4
27.	Restless	0	1	2	3	4
28.	Unable to concentrate	0	1	2	3	4
29.	Fatigued	0	1	2	3	4
30.	Helpful	0	1	2	3	4

Please flip over.
Items continue on the back page...

MHS

The Profile of Moods States 2nd Edition (POMS 2) is authored by Dr. Juvia P. Huechert and Dr. Douglas M. McNair and can be obtained Multi-Health Systems Inc.

POMS™ Standard Form

BY DOUGLAS M. McNAIR, Ph.D., MAURICE LORR, Ph.D., JW P. HEUCHERT, Ph.D., & LEO F. DROPPLEMAN, Ph.D.

POMS™

	Not at all	A little	Moderately	Quite a bit	Extremely
31. Annoyed	0	1	2	3	4
32. Discouraged	0	1	2	3	4
33. Resentful	0	1	2	3	4
34. Nervous	0	1	2	3	4
35. Lonely	0	1	2	3	4
36. Miserable	0	1	2	3	4
37. Muddled	0	1	2	3	4
38. Cheerful	0	1	2	3	4
39. Bitter	0	1	2	3	4
40. Exhausted	0	1	2	3	4
41. Anxious	0	1	2	3	4
42. Ready to fight	0	1	2	3	4
43. Good natured	0	1	2	3	4
44. Gloomy	0	1	2	3	4
45. Desperate	0	1	2	3	4
46. Sluggish	0	1	2	3	4
47. Rebellious	0	1	2	3	4
48. Helpless	0	1	2	3	4
49. Weary	0	1	2	3	4
50. Bewildered	0	1	2	3	4
51. Alert	0	1	2	3	4
52. Deceived	0	1	2	3	4
53. Furious	0	1	2	3	4
54. Efficient	0	1	2	3	4
55. Trusting	0	1	2	3	4
56. Full of pep	0	1	2	3	4
57. Bad-tempered	0	1	2	3	4
58. Worthless	0	1	2	3	4
59. Forgetful	0	1	2	3	4
60. Carefree	0	1	2	3	4
61. Terrified	0	1	2	3	4
62. Guilty	0	1	2	3	4
63. Vigorous	0	1	2	3	4
64. Uncertain about things	0	1	2	3	4
65. Bushed	0	1	2	3	4

Please ensure you have answered every item.
Thank you for completing this questionnaire.

MHS

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APPENDIX D. ACTIVITY LOG EXAMPLE

Marine Aviation Weapons and Tactics Squadron one (MAWTS-1) Sleep, and Performance Study

Activity Log

Naval Postgraduate School

Participant ID: ____________

Beginning Date: ____________

Sleep watch #: ____________

If this log is found, please turn into the NPS Research Team or Maj Matt Bohman, (928)269-3265

General Instructions

The purpose of this project is to investigate the current work and rest schedule of instructors and students at MAWTS-1 and to assess the effect of sleep and fatigue on performance at various times throughout the WTI 2-16 course.

1. Complete all pre-study requirements to include:
   a. Read, and sign both consent forms. Return one of the signed consent forms to a member of the NPS Research Team.
   b. Receive your sleep watch and sign sleep watch roster. You will be given an ID number which will be the number located on the back of your sleep watch.
   c. Receive your activity log.
   d. Complete and return the initial Pre-study Questionnaire.
2. Wear the sleep watch at all times unless:
   a. Directed to remove it by the chain of command.
   b. Engaged in an activity in which you think the sleep watch may become damaged (e.g., diving, swimming, etc.)
3. A subset of students will be asked to perform the 3-minute Psychomotor Vigilance Task (PVT) twice per day.
4. Notify a member of the NPS Research Team ASAP if you have problems with your sleep watch.
5. Record your activities in the sleep log each day (see example on page 4).
6. You will be instructed when to complete the second questionnaire around the midpoint of WTI.
7. At the end of the study
   a. Turn in your sleep watch and activity log.
   b. Take the final Post-study Questionnaire.

The completed questionnaires and activity log will be used for research purposes only. All results will be kept confidential.

Thank you for participating in this study!

NPS IRB
APPROVED
FEB 26 2016
EXPIRES
FEB 17 20[illegible]

Example Log

Two days in the activity / sleep log.
I slept till 0600 (S). I arrived at MAWTS-1 at 0800. I commuted home from 1600 until 1700 (O). I removed my sleep watch from 17015 to 1845 (R). I worked out from 1845 till 2030 (PT). I went to sleep at 2200 until 0600 (S). I began work at 0800. I get off work at 1630, drove home (O), and take a nap for an hour at 1730 (S). I go to sleep at 2320 (S).

Please write legibly and make every effort to be accurate. Thank you for your participation!

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity	S	S	S	S	S	S	O	O									O	R	R	PT	PT/O	O	S	S

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity	S	S	S	S	S	S	O	O									/O	O/S	S/O	O	O	O	O	S

Activities: S = *Sleeping/Napping* PT = *Physical Training* O = *Off-duty/liberty* R = *Actiwatch removed*

Please return this log with your sleep watch to: Nita Lewis Shattuck, Ph.D., Glasgow Bldg., Room 225, (831) 656-2281, nlshattu@nps.edu

Week 1

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Date: _______

Time	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
Activity																								

Activities: S = *Sleeping/Napping* PT = *Physical Training* O = *Off-duty/liberty* R = *Actiwatch removed*

APPENDIX E. STUDY CALENDAR

March and April 2016							
Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**	
	1	2	3	4	5	6 Student Check - in, recruitment, consent, pre-study questionnaires, issue watches & activity logs	Academic Phase
7 Inventory	8	9	10 Generics Exam; Tactical Risk Management Module	11	12	13	
14	15	16	17	18 Commons	19	20	
21	22	23	24	25 Mid-study point: actiwatches collected, actigraphy & PVT data	26	27	
28 Specifics	29	30	31	1	2	3	Flight Phase
4 Commons	5	6	7	8	9	10	
11 Major Evolutions	12	13	14	15	16	17	
18 FINEX	19	20	21	22	23	24 Graduation: watches & activity logs	
25 Questionnaire information extraction , data cleansing and analysis completed at NPS From May through	26	27	28	29	30		

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APPENDIX F. PHASE DAY AND NIGHT ASSIGNMENTS

Omit	Phase	Day of the Week (DOW)	2000	0500	Sleep Night
*	Academic	THU	3/3/2016	3/4/206	1
	Academic	FRI	3/4/2016	3/5/2016	2
	Academic	SAT	3/5/2016	3/6/2016	3
	Academic	SUN	3/6/2016	3/7/2016	4
	Academic	MON	3/7/2016	3/8/2016	5
	Academic	TUE	3/8/2016	3/9/2016	6
	Academic	WED	3/9/2016	3/10/2016	7
	Academic	THU	3/10/2016	3/11/2016	8
	Academic	FRI	3/11/2016	3/12/2016	9
	Academic	SAT	3/12/2016	3/13/2016	10
	Academic	SUN	3/13/2016	3/14/2016	11
	Academic	MON	3/14/2016	3/15/2016	12
	Academic	TUE	3/15/2016	3/16/2016	13
	Academic	WED	3/16/2016	3/17/2016	14
	Academic	THU	3/17/2016	3/18/2016	15
	Academic	FRI	3/18/2016	3/19/2016	16
	Academic	SAT	3/19/2016	3/20/2016	17
	Academic	SUN	3/20/2016	3/21/2016	18
	Academic	MON	3/21/2016	3/22/2016	19
	Academic	TUE	3/22/2016	3/23/2016	20
	Academic	WED	3/23/2016	3/24/2016	21
*	Academic	THU	3/24/2016	3/25/2016	22
*	Academic	FRI	3/25/2016	3/26/2016	23
*	Academic	SAT	3/26/2016	3/27/2016	24
*	Academic	SUN	3/27/2016	3/28/2016	25
	Academic	MON	3/28/2016	3/29/2016	26
	Flight	TUE	3/29/2016	3/30/2016	27
	Flight	WED	3/30/2016	3/31/2016	28
	Flight	THU	3/31/2016	4/1/2016	29
	Flight	FRI	4/1/2016	4/2/2016	30
	Flight	SAT	4/2/2016	4/3/2016	31
	Flight	SUN	4/3/2016	4/4/2016	32
	Flight	MON	4/4/2016	4/5/2016	33
	Flight	TUE	4/5/2016	4/6/2016	34
	Flight	WED	4/6/2016	4/7/2016	35
	Flight	THU	4/7/2016	4/8/2016	36
	Flight	FRI	4/8/2016	4/9/2016	37
	Flight	SAT	4/9/2016	4/10/2016	38
	Flight	SUN	4/10/2016	4/11/2016	39
	Flight	MON	4/11/2016	4/12/2016	40
	Flight	TUE	4/12/2016	4/13/2016	41
	Flight	WED	4/13/2016	4/14/2016	42
	Flight	THU	4/14/2016	4/15/2016	43
	Flight	FRI	4/15/2016	4/16/2016	44
	Flight	SAT	4/16/2016	4/17/2016	45
	Flight	SUN	4/17/2016	4/18/2016	46
	Flight	MON	4/18/2016	4/19/2016	47
	Flight	TUE	4/19/2016	4/20/2016	48
	Flight	WED	4/20/2016	4/21/2016	49
	Flight	THU	4/21/2016	4/22/2016	50
	Flight	FRI	4/22/2016	4/23/2016	51
*	Flight	SAT	4/23/2016	4/24/2016	52
*	Flight	SUN	4/24/2016	4/25/2016	53
*	Flight	MON	4/25/2016	4/26/2016	54

Omit	Phase	Day of the Week (DOW)	0500 -2359	Performance Day	
*	Academic	THU	3/3/2016	0	
	Academic	FRI	3/4/2016	1	
	Academic	SAT	3/5/2016	2	
	Academic	SUN	3/6/2016	3	Student Check-in
	Academic	MON	3/7/2016	4	Inventory Exam
	Academic	TUE	3/8/2016	5	
	Academic	WED	3/9/2016	6	
	Academic	THU	3/10/2016	7	
	Academic	FRI	3/11/2016	8	Generics Exam
	Academic	SAT	3/12/2016	9	
	Academic	SUN	3/13/2016	10	
	Academic	MON	3/14/2016	11	
	Academic	TUE	3/15/2016	12	
	Academic	WED	3/16/2016	13	
	Academic	THU	3/17/2016	14	
	Academic	FRI	3/18/2016	15	Commons Exam
	Academic	SAT	3/19/2016	16	
	Academic	SUN	3/20/2016	17	
	Academic	MON	3/21/2016	18	
	Academic	TUE	3/22/2016	19	
	Academic	WED	3/23/2016	20	
	Academic	THU	3/24/2016	21	
*	Academic	FRI	3/25/2016	22	
*	Academic	SAT	3/26/2016	23	
*	Academic	SUN	3/27/2016	24	
	Flight	MON	3/28/2016	25	
	Flight	TUE	3/29/2016	26	
	Flight	WED	3/30/2016	27	
	Flight	THU	3/31/2016	28	
	Flight	FRI	4/1/2016	29	
	Flight	SAT	4/2/2016	30	
	Flight	SUN	4/3/2016	31	
	Flight	MON	4/4/2016	32	
	Flight	TUE	4/5/2016	33	
	Flight	WED	4/6/2016	34	
	Flight	THU	4/7/2016	35	
	Flight	FRI	4/8/2016	36	
	Flight	SAT	4/9/2016	37	
	Flight	SUN	4/10/2016	38	
	Flight	MON	4/11/2016	39	Major Evolutions
	Flight	TUE	4/12/2016	40	Major Evolutions
	Flight	WED	4/13/2016	41	Major Evolutions
	Flight	THU	4/14/2016	42	Major Evolutions
	Flight	FRI	4/15/2016	43	Major Evolutions
	Flight	SAT	4/16/2016	44	Major Evolutions
	Flight	SUN	4/17/2016	45	Major Evolutions
	Flight	MON	4/18/2016	46	FINEX
	Flight	TUE	4/19/2016	47	FINEX
	Flight	WED	4/20/2016	48	FINEX
	Flight	THU	4/21/2016	49	FINEX
	Flight	FRI	4/22/2016	50	FINEX
*	Flight	SAT	4/23/2016	51	
*	Flight	SUN	4/24/2016	52	
*	Flight	MON	4/25/2016	53	Graduation

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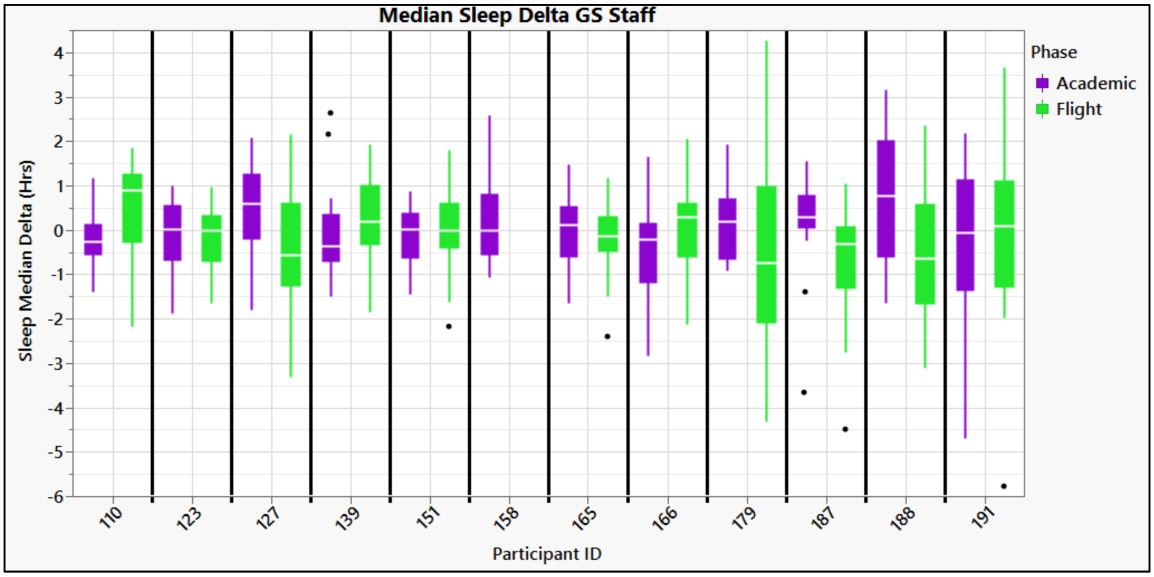
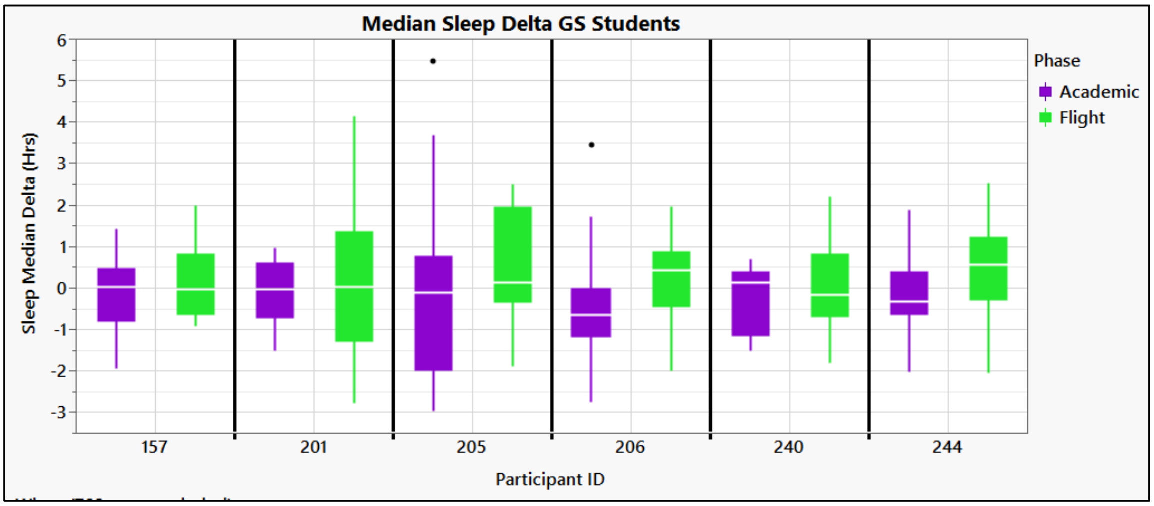
APPENDIX G. GOLD STANDARD (GS) PARTICIPANT SLEEP MEDIAN DELTA





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APPENDIX H. PVT RESPONSE INVENTORY AND CATEGORIZATION

PVT Response Metric	Count	% of Total	% of Valid Responses
Number Unique Trials	2,000		
Total PVT Responses:	46,872	100.00%	
False Starts <100ms:	3,898	8.32%	
Response >=100ms:	42,974	91.68%	
Excluded Responses >=3,000ms:	147	0.31%	
Valid Responses >=100ms & <3,000ms:	42,827	91.37%	100.00%
Lapses >=355ms	3,369	7.19%	7.87%
Valid Responses - Lapses >=355ms	39,458	84.18%	92.13%
Lapses >=500ms	1,622	3.46%	3.79%
Valid Responses - Lapses >=500ms	41,205	87.91%	96.21%

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APPENDIX J. PVT ANALYSIS PROCEDURES

To analyze the output metric 1/RT the following steps were taken:

- Began with 46,872 individual RTs
- Each RT was divided by 1000 and then reciprocally transformed to get 1/RT
- Began with all 1/RTs sorted by “Participant ID” and “Unique Trial ID”
- Removed 4,045 invalid responses (<100ms and >=3,000ms)
- The distribution of the remaining 1,952 unique trials were examined for the number of responses per trial
    - Minimum number of responses 1, Maximum number of responses 46
    - Mean number of responses 21.94 (+/- 2.60)
- 99.5% contained 25 responses
- 2.5% contained 17 responses
- .5% contained 4 responses
- Determined criterial for an incomplete trial
- Removed 42 all incomplete trials (trials with <17 and >=30 valid responses)
    - This equated to 2.2% of all unique trials and left 1,910 useable trials
- Removed 11 trials that occurred during the “Omit Phase Periods” 1,899 remaining trials
    - This was necessary to set up for the phase comparison
- The remaining 82 participants, all had academic trials, 46 participants with 0 trials in the flight phase were removed
    - This may have impacted the student vs. staff comparisons but was necessary to analyze the entire duration of the course
- This left 36 participants. The distribution of number of trials per participant showed between 11 and 66 (with mean 33.58 (+/-13.12); median 30.5)
- Each participant was evaluated for the number of trials they had per phase
- Removed 5 participants with <5 trials in each phase
- 31 remaining participants
- Distributions of mean PVT 1/RTs were analyzed
    - Across the entire duration of the course with all participants
    - By “Status”
    - By “Phase”
- “Phase” comparison was conducted using Wilcoxon / Kruskal-Wallis Tests (Rank Sums) 2-Sample Test, Normal Approximation
- Within-subjects “Status” comparison was conducted using Matched Pairs t-test

To analyze the output metric Error Ratio the following steps were taken:

- Began with all RTs sorted by "Participant ID" and "Unique Trial ID"
- Remove (147) RT Errors (RT ≥ 3,000ms)
- 2,000 unique trials, consider distribution of number of responses
- Maximum number of responses was 58, minimum 1
- Mean number of responses 23.36 (+/- 4.12)
    - 99.5% contained 26
    - 2.5% 8.03
- Removed 75 trials that had either <15 or >30 responses
- This equated to 3.8% of all unique trials and left 1,925 useable trials
- No trials had more than 25 FS
- Removed 11 trials completed during the "Omit Phase"
- Counted the number of trials for 82 each participant
- Removed 50 participants with insufficient (<5) trials
- This left 32 remaining participants for analysis
- Aggregate errors by performance day and how many trials per day, "Daily Errors" and "Daily trials"
- Divided "Daily Errors" by "Daily Trials" to construct "Daily Error Ratio"
- Distributions of mean PVT 1/RTs were analyzed
- Across the entire duration of the course with all participants
    - By "Status"
    - By "Phase"
- "Phase" comparison was conducted using Wilcoxon / Kruskal-Wallis Tests (Rank Sums) 2-sample test, normal approximation
- Within-subjects "Status" comparison was conducted using matched pairs t-test

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